10.0 EVALUATION OF AREAS REQUIRING REMEDIAL ACTION AND IDENTIFICATION OF REMEDIAL ACTION OBJECTIVES AND ARARS

This section includes a summary evaluation of Sauget Area 1 sites including those carried forward to the Feasibility Study (FS) that require remedial action as well as those sites that do not require active remedial action and are not carried forward. This section also identifies the Remedial Action Objectives (RAO) and the Applicable or Relevant and Appropriate Requirements (ARARs) for Sauget Area 1 sites.

10.1 Evaluation of Areas and Media to Be Carried Forward in Feasibility Study

The results of the Human Health Risk Assessment (HHRA) reports and Ecological Risk Assessment (ERA) reports (summarized in Sections 8.0 and 9.0, respectively) have been used to screen the Sauget Area 1 sites to determine which sites are candidates for remedial alternative development in the FS. Constituent concentrations in Sauget Area 1 sites have been evaluated to determine whether environmental media pose a potential risk and/ or hazard above USEPA's target risk range of $1x10^{-6}$ to $1x10^{-4}$ or target hazard index of 1. Sites where current conditions pose potential risk and/or hazard above target levels (referred to as "excess risk" in the remainder of this section) to potential human or ecological receptors have been carried forward in the FS for remedial action development. The screening process for sites in Sauget Area 1 is summarized below and the results of the screening are summarized on Table 10-1.

10.2 Development of Remedial Action Objectives

Remedial Action Objectives (RAOs) are broad, qualitative goals for protecting human and environmental health based on site-specific contaminants, the magnitude of contamination, affected media and potential exposure pathways. RAOs are developed to aid in the identification and screening of appropriate remedial technology alternatives to mitigate existing and future potential threats to human health and the environment. The optimal remedial technology for each Site will address RAOs for the COCs in affected media in the most effective and efficient manner.

For the Sauget Area 1 sites, RAOs have been developed based on the findings of the Remedial Investigation, HHRA and ERA reports as well as the ARARs identified for the sites. This section identifies the sites subject to remedial action alternative screening and the RAOs specific to these sites. Sites where one or more affected media present excess risk to human health and where development of remedial alternatives and RAOs is required include:

- Site G
- Site H
- Site I South
- Site L

Figure 10-1 shows the areas of waste / affected soils at Sites G, H, I South, and L as well as the areas of DNAPL residual in the aquifer matrix underlying Sites G, H, and I South. Figure 10-2 shows the locations of existing and conceptual fencing for access control at these sites. None of sites in Sauget Area 1 posed a potential threat to ecological receptors; therefore, none of the RAOs specifically address ecological risk.

Site G:

- Prevent unacceptable risks to human receptors (i.e., construction workers) resulting from inhalation of COCs found in groundwater and leachate during excavation work.
- Prevent unacceptable risks to human receptors (i.e., construction workers) resulting from ingestion and dermal contact with subsurface soils during excavation work.
- Prevent human exposure to vapor intrusion into indoor air at levels that result in unacceptable risk from COCs in waste material, soils, or groundwater.
- Prevent unacceptable risk related to landfill gas generation.
- Minimize current and future migration of COCs from soil and waste to groundwater at levels causing unacceptable risks.
- Minimize migration of principal threat waste / mobile source material.

Site H

- Prevent unacceptable risks to human receptors (i.e., construction workers) resulting from inhalation of COCs found in groundwater, leachate and subsurface soils during excavation work.
- Prevent unacceptable risks to human receptors (i.e., construction workers) resulting from ingestion and dermal contact with leachate and subsurface soils during excavation work.
- Prevent unacceptable risks to human receptors (i.e., utility workers) resulting from inhalation of COCs found in soil vapor and waste during excavation work on utility lines.
- Prevent unacceptable risks to human receptors (i.e., utility workers) resulting from ingestion or dermal exposure to COCs found in waste materials and soil during excavation work on utility lines.
- Prevent human exposure to vapor intrusion into indoor air at levels that result in unacceptable risk from COCs in waste material, soils, or groundwater.
- Prevent unacceptable risk related to landfill gas generation.
- Minimize current and future migration of COCs from soil and waste to groundwater at levels causing unacceptable risks.
- Minimize migration of principal threat waste / mobile source material.

Site I South

- Prevent unacceptable risks to human receptors (i.e., outdoor industrial/construction workers) resulting from ingestion or dermal exposure to COCs found in surface soils.
- Prevent unacceptable risks to human receptors (i.e., construction workers) resulting from ingestion or dermal exposure to COCs found in surface and subsurface soils and leachate during excavation work.
- Prevent unacceptable risks to human receptors (i.e., construction workers) resulting from inhalation of COCs found in leachate during excavation work.
- Prevent human exposure to vapor intrusion into indoor air at levels that result in unacceptable risk from COCs in waste material, soils, or groundwater.
- Prevent unacceptable risk related to landfill gas generation.
- Minimize current and future migration of COCs from soil and waste to groundwater at levels causing unacceptable risks.
- Minimize migration of principal threat waste / mobile source material.

Site L

- Prevent unacceptable risks to human receptors (i.e., construction workers) resulting from ingestion or dermal exposure to COCs found in subsurface soils during excavation work.

Area-Wide Groundwater

- Prevent ingestion of groundwater exceeding federal MCLs and Illinois Class I drinking water standards.
- To the extent practicable, restore groundwater quality affected by releases from the Sauget Area 1 sites to federal MCLs and Illinois Class I drinking water standards within a reasonable amount of time.
- Prevent groundwater discharges to the Mississippi River from the Sauget Area 1 source areas that result in unacceptable, adverse impact to the Mississippi River.

10.3 Areas and Media That Require Remedial Action

Site G

Site G is a roughly 3.3-acre parcel that was operated as a waste disposal site from sometime after 1940 to 1966, with potentially some intermittent dumping through 1982, when most of the site was fenced. Site G was subject to a removal action in 1995. Surface and subsurface soil sampling data from the Remedial Investigation were used to evaluate exposure pathways in the site-wide HHRA (ENSR, 2001) and the Vapor Intrusion (VI) HHRA (AECOM, 2009a). At the request of USEPA, additional information regarding chemical use at the Wiese Building located on the site was presented in a memorandum in 2009 (AECOM, 2009b). A summary of the Site G scenarios and risk screening processes are provided in Tables 8-1 through 8-8.

Because the property is currently zoned for commercial/industrial use, the scenarios investigated in the HHRA include potential commercial/industrial receptors. Potentially complete exposure pathways for Site G include inhalation pathways for indoor and outdoor workers, construction workers and trespassers, and ingestion/dermal contact exposure for outdoor workers, trespassers, and construction workers. The HHRA identified benzene, chlorobenzene, and naphthalene as COCs for the inhalation pathway from groundwater and leachate, and phosphorous and PCBs for ingestion and dermal contact with subsurface soils. Site G is carried forward for development of remedial alternatives in the FS based on exceedences of target risk levels for the construction worker scenario.

There are several other reasons to carry forward Site G that are based on potential ARARs for the Sauget Area 1 sites. For Site G these include the need to minimize leaching of COCs from soil and waste to groundwater, the need to control migration of dissolved phase constituents from residual DNAPL in the aquifer matrix, the potential risk from vapors and landfill gas, and to the extent practicable, restore groundwater quality affected by releases from the Sauget Area 1 sites to federal MCLs and Illinois Class I drinking water standards.

Site H

Site H is an approximately 4.9-acre tract that used to be connected to Site I South (Figure 10-1). Site H and Site I South together were known to be part of the “Sauget Landfill", which was originally used as a sand and gravel pit and then received industrial and municipal wastes from approximately 1931 to 1957. Site H and Site I South are separated at ground level by Queeny Avenue (see Figure 10-1). Queeny Avenue was constructed at its present location in 1949 or 1950.

During a subsurface utility corridor investigation in 2008, waste was observed in three of the four borings in the utility corridor at Site H on the south side of Queeny Avenue and two of the four borings in the utility corridor at Site I South on the north side of Queeny Avenue (Golder, 2008). Based on these observations, there is no conclusive evidence to indicate that waste does not also exist at some locations beneath Queeny Avenue between Site H and Site I South. For the purpose of site screening, the utility corridor along Site H and Site I South was included in the risk assessment results.

The site-wide HHRA (ENSR, 2001) evaluated potentially complete exposure pathways for outdoor, construction and utility workers as well as the teenage trespasser scenarios. The Utility Corridor HHRA (ENSR, 2008) evaluated potentially complete exposure pathways for utility workers. Potential risks calculated for Site H show exceedences of the USEPA target risk range for the utility worker and exceedences of the target HI for the construction and utility worker scenarios. The following constituents were identified as COCs for Site H: benzene, cadmium, chloroform, manganese and PCBs for the construction worker and PCBs, 2,3,7,8-TCDD-TEQ, 4,4-DDD, 4,4-DDT, chlorobenzene, dieldrin, and barium for the utility worker. Environmental media that present excess risk/hazard include soil, waste, subsurface soil, and excavation air from soil, groundwater and leachate. Site H has been carried forward for remedial action alternative screening in the FS based on exceedences of target risk levels for the construction worker and utility worker scenarios.

Results of a toxicity evaluation identified potential risks greater than the USEPA's principal threat waste toxicity threshold of 10^{-3} in waste samples from the utility corridor south of Queeny Avenue at Site H (ENSR, 2008). Constituents with potential risks above 10^{-3} include PCBs and 2,3,7,8-TCDD-TEQ.

Based on potential ARARs for the Sauget Area 1 sites, other reasons to carry forward Site H include the need to minimize leaching of COCs from soil and waste to groundwater, the need to control migration of dissolved phase constituents from residual DNAPL in the aquifer matrix, the potential risk from vapors and landfill gas, and to the extent practicable, restore groundwater quality affected by releases from the Sauget Area 1 sites to federal MCLs and Illinois Class I drinking water standards.

Site I South

Site I South consists of approximately 8.8 acres and used to be connected to Site H. Site H and Site I South together were known to be part of the "Sauget Landfill", which was originally used as a sand and gravel pit and then received industrial and municipal wastes from approximately 1931 to 1957. Site H and Site I South are separated at ground level by Queeny Avenue (see Figure 10-1), which was constructed at its present location in 1949 or 1950. Site I South is located on an active industrial facility and is within the fenced area of the facility (Figure 10-2).

The site-wide HHRA (ENSR, 2001) evaluated potentially complete exposure pathways for the outdoor and construction worker and trespasser scenarios. The Utility Corridor HHRA (ENSR 2008) evaluated potentially complete exposure pathways for utility workers. The VI HHRA (AECOM, 2009a) extended the analysis to indoor workers in a building adjacent to Site I South. Potential risks calculated for Site I South show exceedences of the USEPA target risk range for the outdoor industrial worker and exceedences of the target HI for the construction worker and outdoor industrial worker scenarios. The following COCs were identified: 2,3,7,8-TCDD-TEQ and PCBs for the outdoor industrial worker and PCBs, antimony, chlorobenzene, chloroform, MCPP, and naphthalene for the construction worker. Environmental media that present excess risk/hazard include surface soil, subsurface soil and leachate, as well as excavation air from leachate. Based on the results of the HHRA, Site I South is included in development of remedial alternatives in the FS based on exceedences of target risk levels for the construction worker scenario and the outdoor industrial worker scenario.

Pooled DNAPL is present at bedrock well BR-I, which is located at Site I South. Pooled DNAPL is a source material and may be considered a principal threat waste liquid.

Based on potential ARARs for the Sauget Area 1 sites, other reasons to carry forward Site I South include the need to minimize leaching of COCs from soil and waste to groundwater, the need to control migration of dissolved phase constituents from residual DNAPL in the aquifer matrix, the potential risk from vapors and landfill gas, and to the extent practicable, restore groundwater quality affected by releases from the Sauget Area 1 sites to federal MCLs and Illinois Class I drinking water standards.

Site L

Site L comprises roughly 7,600 square feet and is located immediately east of Dead Creek (Figure 10-1). The Site was used for the disposal of wash-water from truck cleaning operations between 1971 and 1981.

The HHRA evaluated potentially complete exposure pathways for the outdoor worker, construction worker, and trespasser scenarios. Based on the results of the HHRA (ENSR, 2001) PCBs in the subsurface soil are identified as the only COC. PCBs were found to pose a potential HI above the USEPA target level for ingestion of or dermal contact with subsurface soils for the construction worker scenario. Therefore, Site L is included in development of remedial alternatives in the FS based on exceedences of target risk levels for the construction worker scenario.

Area-Wide Groundwater

Groundwater in the Alluvial Aquifer flowing beneath Sauget Area 1 moves to the west and ultimately discharges to the Mississippi River, approximately 5,700 feet downgradient of the western boundary of Sauget Area 1. Three hydrogeologic units can be identified at Sauget Area 1: the Shallow Hydrogeologic Unit (SHU), Middle Hydrogeologic Unit (MHU), and Deep Hydrogeologic Unit (DHU).

VOCs and SVOCs are the principal contaminants in groundwater. As the plumes from Sauget Area 1 move toward the west, they combine with plumes originating from sources at other sites in the Sauget region, including Sauget Area 2 sites, Clayton Chemical, and the W.G. Krummrich facility. Approximately 73% of the Sauget Area 1 plume that reaches the area near the River is intercepted by the GMCS at Sauget Area 2 Site R.

Figures 10-3, 10-4, and 10-5 show the approximate extent of detected constituents that exceed the federal MCLs and Illinois Class I drinking water standards in the SHU, MHU, and DHU, respectively.

There are a total of nine indicator constituents for groundwater at and downgradient of the Sauget Area 1 source areas. The nine indicator constituents include six VOCs (benzene, chlorobenzene, tetrachloroethene, trichloroethene, 1,2-DCE, vinyl chloride), two SVOCs (1,4-dichlorobenzene and 4-chloroaniline), and one herbicide (2,4-D).

A recommendation for consideration of remedial options for area-wide groundwater is based on the following considerations: i) the need to ensure no ingestion of groundwater exceeding federal MCLs and Class I drinking water standards; ii) the need to eventually restore groundwater quality to federal MCLs and Illinois Class I drinking water standards, to the extent practicable; and iii) the need to prevent groundwater discharges to the Mississippi River from the Sauget Area 1 source areas that result in unacceptable, adverse impacts to the Mississippi River.

10.4 Sites Screened from Active Remediation

The sites described below are not carried forward in the FS for active remediation. However, the remedial alternatives for Sauget Area 1 do include long-term operation and maintenance (O&M) and institutional controls for the Judith Lane Containment Cell.

Dead Creek and Borrow Pit Lake

Segment A: Dead Creek includes Segments A, B, C, D, E, and F and the Borrow Pit Lake. (Site M is discussed in the next section.) Dead Creek Segment A was remediated under an IEPA-approved plan during 1990 and 1991. Remedial activities for Segment A consisted of excavating creek bed soils to 10 to 15 feet in depth, then covering and backfilling the area with crushed gravel. The excavated soils from Segment A were taken to various Waste Management disposal facilities. Remedial activities for Segment A are detailed in a 1991 report (Cerro Copper Products, 1991). Segment A is within the fenced area of the Cerro Flow Products facility (Figure 10-2).

The potentially responsible parties (PRPs) plan to voluntarily place institutional controls on Segment A. The institutional controls could include maintenance of the existing fence at the Cerro Flow Products facility and filing of deed notices or restrictions.

Segments B through F and Borrow Pit Lake: Segments B through F and the Borrow Pit Lake were the subject of the Unilateral Administrative Order (UAO) issued in 1999 and amended in 2000 and 2001 authorizing a time-critical removal action. Under the order, 46,000 cubic yards of sediments were removed from the creek bed. In 2005-2006, additional remediation was conducted that resulted in removal of 12,400 cubic yards of creek bottom soils and sediments from Borrow Pit Lake exceeding the site-specific RBCs protective of forage fish. An armored impermeable liner was installed throughout Creek Segment B in 2008. Details of sediment concentrations and excavation activities for the Dead Creek Site including the Borrow Pit Lake are provided in Section 2.3.

As noted in Section 9, although some exceedances of ecological screening values likely remain in certain areas after the completion of the removal actions, the site-specific ecological evaluation does not indicate that additional remedial action alternatives should be considered within Dead Creek. The use of Creek Segments C, D and E for stormwater conveyance from a variety of upland sources and the variable water level conditions within the creek result in an area that does not provide significant suitable habitat for terrestrial organisms. Since these conditions limit the available habitat and represent substantial stressors for ecological receptors, additional remedial action for the creek bottom soils is not recommended.

Segment B is protected by a fence (Figure 10-2) and, as noted above, has an armored impermeable liner throughout its entire length. The PRPs plan to voluntarily place institutional controls on Segment B. The institutional controls could include maintenance of the existing fence and filing of deed notices or restrictions.

Judith Lane Containment Cell: Excavated sediments and soils from Creek Segments B through F and the Borrow Pit Lake were transferred to the Judith Lane Containment Cell ("Containment Cell") shown on Figure 10-1. The Containment Cell was constructed to meet RCRA and TSCA requirements. There are currently plans to add PCB-affected soils (excavated at the W.G. Krummrich facility) to utilize unused Containment Cell capacity. After these soils are added, the final engineered cover for the Containment Cell will be placed. Once the final cover has been placed, the cell will require long-term O&M including inspections, sampling of primary and secondary leachate, collection and treatment of leachate, sampling and testing of groundwater monitoring wells, and maintenance and repairs as needed.

A Remedial Action Project Plan (RAPP) that is being reviewed by the RCRA division of Illinois EPA provides detailed information on the construction of the final cover, the Groundwater Monitoring Plan, Emergency and Contingency Plan, Closure and Post Closure Plan, and other details regarding the Judith Lane Containment Cell. Once comments are received from Illinois EPA, the RAPP application will be modified and submitted for approval. After all approvals are obtained, the PCB-affected soils will be placed into the Containment Cell and the final cap will be installed.

Containment Cell O&M has been included as a remedy component in the remedial alternatives developed for Sauget Area 1. Institutional controls such as fencing and deed notices or restrictions will also be needed for the Containment Cell. The long-term Illinois EPA RCRA requirements will be incorporated into an appropriate CERCLA enforceable document, and at that point Illinois EPA plans to turn the oversight of the long-term site operations over to CERCLA.

Site M

Site M is a historic borrow pit that was connected to Dead Creek through an opening at its southwest corner, allowing water from the Creek to enter the pit. Contaminated sediments were removed from Site M in 2000-2001 as part of the UAO Time-Critical Removal Action. Site M has been backfilled as part of the removal action, and access to the site is currently restricted by a fence. Due to the previous remedial activities conducted under the UAO, Site M is not considered for further remedial action in the FS.

Site I North

Site I North comprises approximately 5.9 acres and is within the fenced area of the Cerro Flow Products facility. Site I North was not part of the “Sauget Landfill” operations described above (regarding Site H and Site I South). Historically, inert fill materials (e.g., brick, concrete, and other construction debris) were used to fill low areas and maintain grades at Site I North. An evaluation of potential risks associated with Site I North is presented in a technical memorandum found in Appendix A. While low levels of COCs were detected in Site I North samples, concentrations in this area are below levels that trigger excess risk or hazard. Based on the technical memorandum in Appendix A, no COCs are associated with Site I North and, therefore, Site I North is not included for remedial action development in the FS.

Site N

Site N is an approximately 4-acre historic borrow pit formerly owned by the H. Hall Construction Company. The borrow pit was primarily used to dispose of construction and demolition debris and may have contained some painting or chemical wastes. Access to Site N is currently limited by a fence. Site sampling results indicated very low levels of VOCs and SVOCs in soils. At the request of USEPA, Site N was evaluated for both commercial/industrial as well as a hypothetical future residential scenario. Based on the results of site-wide HHRA, potential risks and HIs calculated for Site N are all below USEPA targets for both commercial/industrial and residential receptors. Site N is not carried forward in the FS.

Residential Transects

Floodplain soil samples were collected from residential transects and subsequently used to assess risk in the site-wide HHRA (ENSR, 2001) for residential areas near Sauget Area 1. The transect areas are shown in Figure 3-10, and include both residential and commercial property as well as undeveloped land. Both residential and commercial/industrial scenarios were evaluated for these areas. Results of the HHRA for the transects indicate no exceedances of target risk or hazard levels for potential residential or non-residential receptors in these areas. Therefore, areas along the transects are not included in remedial alternative development in the FS.

10.5 Identification of Applicable or Relevant and Appropriate Requirements (ARARs)

As part of the FS process, remedial action technologies must be identified that achieve a level or standard of control that attains each legally applicable or relevant standard for every medium that may pose excess risk. ARARs provide the regulatory context in which the RAOs are developed. ARARs are federal and state regulatory requirements related to human and ecological health that are used to 1) evaluate the appropriate extent of site cleanup, 2) help scope and formulate the remedial alternatives to be screened, and 3) influence the implementation and operation of the selected remedial action.

In addition to ARARs, other non-promulgated advisories or guidance known as ‘To Be Considered’ (TBC) criteria can be proposed to supplement the ARARs. TBCs are issued by federal or state governments and can be used in determining the necessary level of cleanup to achieve protection of potential receptors. The TBCs are not legally binding, but can be effective methods to derive appropriate end-points for cleanup. Both potential ARARs and TBCs have been identified for the Sauget Area 1 sites and are listed in Table 10-2

EPA Guidance for RI/FS (EPA, 1988) describes three functional groups of ARARs that must be evaluated:

Chemical Specific ARARs

Chemical-specific ARARs are health-based or risk-based values that define acceptable exposure concentrations or water quality standards. These requirements can provide numerical cleanup standards for different media. Chemical-specific ARARs govern the extent of remediation required for a specific medium by providing either a numerical standard or a basis for the calculation of a standard (such as a tiered approach). Remedial technologies for a site can be screened based on the level of cleanup specified by the ARAR. The future success of the remedial alternative may be judged relative to these standards.

Location-Specific ARARs

Location-specific ARARs may restrict remediation activities at sensitive or hazard-prone locations such as active fault zones, wildlife habitats, flood zones or wetlands. Location-specific ARARs define standards for permitted hazardous waste transfer, treatment, storage and disposal (TSD) and put limitations on TSD facilities in areas that may pose seismic or flooding hazard or harm to sensitive habitat or archeological resources. These ARARs place restrictions on concentrations of hazardous substances or the conduct of certain activities solely based on the site’s characteristics and location.

Action-Specific ARARs

Action-specific requirements may control other activities or technologies associated with design, installation and implementation of the remedial options. Action-specific ARARs address the technology and activities of treatment, transportation, and disposal of hazardous waste. This category of ARAR is generally associated with performance and/or design standards, controls, or restrictions on the technologies associated with the remedial action alternatives.

Table 10-2 lists 70 potential ARARs identified for the Sauget Area 1 Sites. ARARs are discussed in more detail in Section 13.0. Table 13-1 provides the classification and rationale for classification for each ARAR and provides a demonstration of compliance as part of the detailed evaluation of five remedial action alternatives. The ARAR classifications used on Table 13-1 include Applicable, Not Applicable, Relevant and Appropriate, Relevant but Not Appropriate, and To Be Considered. Waivers of ARARs are not anticipated to be required for Sauget Area 1.

11.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

This section identifies general response actions and identifies and screens remedial technologies that may be applicable to the Sauget Area 1 sites.

11.1 General Response Actions

The first step in determining applicable technologies for remediation is the identification of the types of response actions that will satisfy the RAOs developed in Section 10. General response actions (GRAs) are general methods by which COCs may be controlled, contained, removed, treated, and/or disposed to mitigate risks to human health and the environment. GRAs include the following approaches (EPA, 1985):

- **No action** – The status quo is maintained; no remedial action is performed. The CERCLA process requires this GRA for comparative purposes.
- **Institutional controls only** – Institutional controls are used to limit access to the affected media. Examples of institutional controls are deed recordation, fencing, signs, and other methods to limit site access.
- **Containment / Capping / Covering** – Physical barriers are used to prevent contact with the affected media. Containment may consist of surface barriers such as paving or capping with soil, and/or subsurface barriers, such as slurry walls or sheet piling. Containment for affected groundwater can also be achieved hydraulically with groundwater extraction.
- **Excavation / Removal** – The affected medium is removed for treatment and/or disposal at another location, thereby preventing contact with potential receptors.
- **Treatment** – The volume, concentration, mobility, and/or toxicity of the affected medium are reduced by transforming or destroying the COCs through treatment. Treatment may be completed in-situ (in place) or ex-situ (after removal from its original location).
- **Disposal** – The affected medium is placed in a secure location where contact with potential receptors is prevented, such as an on-site or an off-site landfill.

11.2 Identification and Screening of Remedial Technologies

For each GRA there may be several general technology categories potentially applicable to the site. During remedial process alternative screening, these general technologies are identified and several specific process options under each technology may be considered. For example, under the treatment GRA, biological treatment represents a class of potentially applicable treatment processes. Under biological treatment, ex-situ biological slurry treatment would be one specific process option. Once identified and defined, technologies and process options are screened to eliminate options that do not fulfill the following basic screening criteria:

- **Effectiveness**: Short-term and long-term effectiveness and reductions in toxicity, mobility, or volume are assessed under this criterion.
- **Implementability**: Technical and administrative feasibility are considered under this criterion. A careful consideration of the technical feasibility of various options is performed given the existing hydrogeologic setting, site improvements, and site COCs. Technical feasibility is defined as the ability to construct, reliably operate, and meet regulatory, O&M, and monitoring requirements. If a technology has not been sufficiently developed, it is considered to be infeasible for the purpose of the feasibility study. Administrative feasibility evaluates the effect of non-technical issues on the implementability of alternatives. These non-technical issues include obtaining regulatory approval or permits.
- **Relative Cost**: Relative cost is the relative capital and O&M costs associated with a process option. Costs are estimated using engineering judgment and are presented as

higher than average, average, or lower than average. Cost comparisons are performed between process options that are in the same technology type. Relative cost is used to eliminate options that are substantially more expensive than other process options.

Remedial technologies were identified from the Remediation Technologies Screening Matrix and Reference Guide (Federal Remediation Technology Roundtable, 2006) and USEPA guidance manuals. Technologies were limited to those that are proven effective; technologies at the research stage or those that have not been successfully implemented in the field were not considered.

The initial identification of potential technologies and process options for soil and waste is shown on Table 11-1 and for leachate and groundwater on Table 11-2. The tables provide a brief description of each process option and a qualitative evaluation of its effectiveness, implementability, and relative cost. The table also provides a rationale for elimination of technologies and process options that have been screened out. At this preliminary stage, technologies are screened based mainly on effectiveness and implementability, with relative cost being used only to eliminate those process options that are clearly not cost competitive with other options within a technology category.

The information presented on Tables 11-1 and 11-2 is sufficient for identification and initial screening of various technologies that may be applicable to the Sauget Area 1 sites (e.g., engineered covers, excavation and disposal, groundwater extraction and treatment, monitored natural attenuation), and these commonly used technologies are not discussed further in this section of the FS. Section 11.3 provides additional discussion for initial screening of potential technologies for addressing the residual DNAPL source areas in the Alluvial Aquifer, including surfactant treatment, thermal treatment, chemical oxidation, and enhanced bioremediation.

11.3 Evaluation of Potential DNAPL Source Depletion Technologies

11.3.1 Results of Treatability Evaluations Performed During the DNAPL Characterization and Remedation Study

As discussed in Section 4.2.1.4, the DNAPL characterization and remediation study included treatability evaluations for three potential DNAPL source depletion technologies: surfactant flushing, thermal treatment, and chemical oxidation. As discussed below, these technologies are screened out from further consideration for Sauget Area 1.

Surfactant Treatability Evaluation - Surfactant flushing (with or without cosolvent) has been developed as an aggressive remediation technology for DNAPL contamination in the subsurface (Yin and Allen, 1999). Results of a surfactant treatability test using a DNAPL sample from Sauget Area 1 showed no consistent enhancements in solubilization of COCs. This suggests that surfactant-enhanced solubilization is not an appropriate technology selection for Sauget Area 1.

Thermal Treatment Evaluation - Thermal treatment is a general term for a variety of approaches designed to destroy or mobilize constituent mass *in situ*. Most methods involve the injection of heat (often in the form of steam) to vaporize and strip volatile compounds. It is not practical to dewater or completely boil off all water within the saturated zone at Sauget Area 1. One thermal treatment approach that does not require dewatering of the saturated zone is a combination of Dynamic Underground Stripping and Hydrous Pyrolysis Oxidation (DUS/HPO). The DUS/HPO process involves the continuous injection of steam and oxygen to heat the aquifer to the boiling point of water and mobilize a portion of the contamination through volatilization and stripping. Recovery of volatilized constituents requires a series of extraction wells. Hydraulic control is used to recover a portion of the overall mass, including mobilized free product and aqueous phase constituents.

Laboratory analysis of the DNAPL sample from BR-I indicated that the principal constituents by mass fraction were 1,2,4-trichlobenzene (14%); hexachlorobenzene (1%); and 1,4-dichlorobenzene (0.8%). These chemicals have minimum boiling points of 416°F, 630°F, and 346°F, respectively. Distillation test results using DNAPL from BR-I indicate that only 5% of the DNAPL has a boiling point at or below 432°F. The remaining 83% of the sample volume recovered had a boiling point that fell within the relatively narrow range of 432 to 530°F. These laboratory results are documented in Appendix C of the DNAPL Characterization and Remediation Report (GSI, 2006c)

Based on results from the BR-I DNAPL sample, the DNAPL constituents within the fill materials and Alluvial Aquifer matrix at Sauget Area 1 have relatively high boiling points, which indicates that volatilization is not likely to be the predominant source removal mechanism during thermal treatment using the DUS/HPO technology. Instead the predominant mass removal mechanism would likely be pumping of free product, based on results from the Visalia site, a well-documented site located in Visalia, California, where DUS/HPO thermal treatment technology was applied (US DOE, 2000). Heating of the fill materials and aquifer matrix at Sauget Area 1 would reduce interfacial tension and viscosity of residual DNAPL, thereby increasing the potential for DNAPL to move through the fill and aquifer matrix and be removed by pumping from recovery wells.

Due to the thickness and permeability of the Alluvial Aquifer at Sauget Area 1, it would take a very large amount of electrical energy to heat the aquifer to the boiling point of water, even for a small pilot-scale project. Due to high capital costs and very high energy costs, it would be cost prohibitive to scale up in-situ thermal treatment technology for the entire source areas at Sites G, H, and I South. Therefore, in-situ thermal treatment technology was screened from further consideration.

Chemical Oxidation Treatability Evaluation - Chemical oxidation acts to deplete source mass via a chemical reaction between a strong oxidant with a reduced constituent with the goal of directly converting the compound to CO_2. Common chemicals used for this purpose include hydrogen peroxide (H_2O_2), chloride dioxide (ClO_2), and potassium permanganate ($KMnO_4$). Potassium permanganate has been used for removing drinking water pollutants for several decades, and it has been applied in field demonstrations for removing DNAPL at the Borden site (Schnarr et al., 1998) and at the Portsmouth Gaseous Diffusion Plant in Ohio (U.S. DOE). On this basis, potassium permanganate was the chemical oxidant that was selected for further evaluation at Sauget Area 1.

Results of a chemical oxidation treatability test on a DNAPL sample from the W.G. Krummrich facility showed that the test was not successful in converting all VOCs to carbon dioxide. The tests yielded ratios ranging from 15.7 to 148.3 grams of permanganate needed per gram of VOC oxidized, in part because the oxidation reaction was kinetically limited and non-selective. Because the Krummrich DNAPL is generally similar in composition to that recovered at Sauget Area 1 (chlorinated benzenes), it is not expected that chemical oxidation would be an effective source depletion technology at Sauget Area 1.

11.3.2 Evaluation of Enhanced Bioremediation for DNAPL Source Depletion

Enhanced bioremediation technologies involve increasing the rate of biodegradation of organic contaminants by stimulating the activity of naturally occurring microbes. Enhanced bioremediation can be performed under aerobic conditions or anaerobic conditions.

Enhanced aerobic bioremediation involves the addition of air, oxygen, or an oxygen-releasing compound to increase the oxygen content in the saturated zone and promote aerobic biodegradation. Chlorobenzene and 1,4-dichlorobenzene, which are present at elevated concentrations in the residual DNAPL source areas, are the COCs with the highest concentrations and greatest extent at Sauget Area 1. Both are readily degradable under aerobic conditions. As discussed in Section 6.3, benzene, vinyl chloride, p-chloroaniline, and 2,4-D are also aerobically degradable.

PCE, TCE, and 1,2-DCE do not readily degrade in aerobic environments. In anaerobic environments they undergo reductive dechlorination in a stepwise process, with PCE dechlorinated to TCE, DCE (primarily the cis-1,2-DCE isomer), vinyl chloride, and finally ethene. PCE, TCE, and 1,2-DCE tend to be recalcitrant in aerobic environments because reductive dechlorination is not energetically favorable and dechlorinating microbes are inhibited by oxygen.

Enhanced anaerobic bioremediation involves addition of a degradable substrate (e.g., vegetable oil) to the saturated zone that ferments and produces hydrogen, which is used in reductive dechlorination of COCs. Enhanced anaerobic biodegradation would be effective for addressing PCE, TCE, and 1,2-DCE. Chlorobenzene, 1,4-dichlorobenzene, and benzene can also degrade anaerobically. However, anaerobic biodegradation pathways often involve potentially harmful intermediates, and further transformation of these intermediates can be limited relative to the parent COCs due to a variety of factors (e.g., lack of organisms that perform subsequent steps in the degradation pathway, less energy available, chemical structure is difficult to attack). Examples include accumulation of benzene from chlorobenzene/dichlorobenzene dechlorination (Furg et al, 2009) and accumulation of cis-1,2-DCE from PCE/TCE dechlorination (Hendrickson et al., 2002).

Enhanced aerobic biodegradation is generally preferable to implement compared to enhanced anaerobic biodegradation because a gas (pure oxygen or air) is easier to deliver and distribute in the Alluvial Aquifer than a liquid organic substrate (e.g., vegetable oil). Due to the thickness and permeability of the Alluvial Aquifer at Sauget Area 1, it would take a very large volume of a liquid organic substrate to promote enhanced anaerobic bioremediation of the Sauget Area 1 residual DNAPL source areas. Furthermore, adding a large volume of degradable substrate could degrade the general water quality of the Alluvial Aquifer in the areas where the material was injected. Consideration of these negative impacts on secondary water quality is included in guidance documents on enhanced anaerobic bioremediation (AFCEE, 2004; ITRC, 2008) and it represents a significant enough problem that the Department of Defense continues to fund several major research projects to better understand this topic (SERDP, 2011a, 2011b). Therefore, enhanced anaerobic bioremediation was screened from further consideration.

Enhanced aerobic bioremediation could potentially be an effective source depletion technology for reducing the mass of COCs in the residual DNAPL source areas at Sauget Area 1 and is retained for further evaluation. Enhanced aerobic bioremediation would not address PCE, TCE, or 1,2-DCE. However, these are not the principal constituents in the residual DNAPL source areas at Sauget Area 1.

Air sparging is a technology that can be used to add oxygen to the saturated zone. Air sparging involves the injection of air into an aquifer through vertical or horizontal wells, and it can remove COCs by volatilization and by in-situ aerobic biodegradation. Air sparging systems are coupled with soil vapor extraction (SVE) systems in situations where vapor migration could cause adverse impacts. Biosparging is a particular mode of air sparging operation that emphasizes aerobic biodegradation over volatilization. Biosparging systems are typically designed to operate without an SVE system.

Pure oxygen can also be sparged into the saturated zone. Pure oxygen sparging has the advantage of delivering much higher concentrations of oxygen to the subsurface compared to air sparging, but it is more costly and may have health and safety concerns regarding oxygen accumulation below buildings.

11.4 Initially Retained Technologies

Initially retained technologies from Table 11-1 for soil and waste include landfill caps and excavation with off-site disposal. Initially retained technologies and process options from Table 11-2 for leachate and groundwater include monitored natural attenuation, air sparging with soil vapor extraction, biosparging, and groundwater pump and treat. Based on the discussion in Section 11.3, air sparging with SVE and biosparging are the initially retained technologies for reducing source mass in the residual DNAPL areas within the Alluvial Aquifer.

Initially retained technologies from Table 11-2 for ex-situ treatment of produced water include oil-water separation, air stripping, granular activated carbon, and precipitation/ coagulation/ flocculation. Initially retained technologies from Table 11-2 for ex-situ treatment of recovered vapors include oxidation and vapor-phase carbon adsorption.

12.0 DEVELOPMENT AND SCREENING OF ALTERNATIVES

This section develops a range of potential remedial alternatives for Sauget Area 1 using the technologies and process options that were retained after the screening and evaluation completed in Section 11. Each alternative consists of multiple technologies and supporting elements that form a complete approach to accomplishing the RAOs for each media.

This section also includes an initial screening of the potential remedial alternatives based on effectiveness, implementability, and relative cost.

12.1 Development of Remedial Alternatives

12.1.1 Descriptions of General Process Options and Technologies

The following general response actions and technologies retained from screening in Section 11 were used in development of the alternatives for Sauget Area 1.

No Action – As required by CERCLA, a No Action alternative must be included as a remedial alternative to provide a baseline for evaluation of the remedial alternatives. The No Action alternative does not involve any treatment, removal, or monitoring.

Institutional Controls – Institutional controls are a component of each alternative developed for Sauget Area 1 except the No Action alternative. Institutional controls are access restrictions or land use restrictions designed to control access to the sites, manage construction or other intrusive activities that may disturb soil or waste, and minimize potential exposure to COCs.

Engineered Covers – Engineered covers include landfill covers, caps, or other barriers to minimize the potential for exposure to COCs in soils and waste in covered areas. The types of engineered covers selected for a remedial alternative will vary depending on the existing uses of the sites and the types of fill or waste materials that are present at the sites. The cover designs will also vary depending on whether or not the alternative includes technologies that introduce air into the saturated zone beneath the covered area (e.g., air sparging or biosparging). Permeable covers are more appropriate in these situations.

The types of engineered covers that were considered in potential remedial alternatives for Sauget Area 1 include RCRA Subtitle C covers, asphalt covers, soil covers, and crushed rock covers.

RCRA Subtitle C covers are multi-layer caps that promote surface water drainage and minimize surface water infiltration. They include a low permeability layer underlain by a gas collection layer and overlain by a drainage layer and protective soil cover and vegetative layer. At traffic areas, the surface layer of a RCRA Subtitle C cap can be constructed of alternate materials such as crushed rock or asphalt pavement.

Asphalt covers include a prepared subgrade, aggregate base, and asphalt surface layer. The thickness of these layers can be tailored to site-specific conditions.

Soil covers utilize a layer of clean soil to minimize potential for contact with COCs in the underlying affected soil and waste. Vegetation is established on the soil cover to minimize the potential for erosion. The soil covers that are included in the alternatives for Sauget Area 1 would meet the requirements in Illinois Administrative Code Title 35 Part 807 (35 IAC 807) for solid waste landfill covers. The principal requirement is installation of a compacted layer of not less than two feet of suitable material.

Crushed rock covers use granular material to cover an area and minimize potential for exposure to COCs in soil and waste. The granular material can be free-draining or less permeable material, depending on site-specific conditions (i.e., traffic vs. non-traffic areas).

Each type of engineered cover described above would require long-term inspection and maintenance. In addition, the Judith Lane Containment Cell will require long-term O&M.

Excavation and Off-Site Disposal – This process option would involve excavation of soil and waste materials from Sites G, H, I South, and L, transportation to an approved and permitted off-site facility, and treatment and/or disposal at the off-site facility. Since PCBs are present in some of the waste materials, the disposal facility may need to be permitted to dispose of PCB-contaminated materials. Source area waste volumes were estimated in Section 3.2.3.3. As summarized below, the total in-place and loose volumes for Sites G, H, I South, and L total 636,000 cubic yards and 827,000 cubic yards, respectively. The estimated loose volumes were calculated using a multiplier of 1.3.

Disposal Area	Estimated In-Place Volume (cubic yards)	Estimated Loose Volume (cubic yards)
Site G + Site G West	107,000	139,000
Site H	157,000	204,000
Site I South	355,000	461,000
Site L	17,500	23,000
Total	636,000	827,000

Utility Relocation – Utilities can be relocated to prevent unacceptable risks to utility workers during excavation work on utilities. This remedy component is included in the alternatives for Sauget Area 1 to prevent utility workers from potentially coming into contact with wastes in the utility corridor along Queeny Avenue adjacent to Site H. The waste materials in the Site H utility corridor were found to be principal threat wastes based on a toxicity evaluation, as discussed in Section 5.2.3.3 and Section 8.0. Utility relocation will also involve relocation of a municipal water line that crosses Site I South.

Recovery of Pooled DNAPL – This is a removal technology that involves recovery of an accumulation of DNAPL that is pooled at the base of a water-bearing zone. The DNAPL is pumped from an extraction well and collected in a tank. When a sufficient volume has accumulated in the tank, the DNAPL is transported off-site for disposal at a permitted facility. Off-site incineration is a typical disposal method for DNAPL.

The pooled DNAPL that is present at well BR-I at Site I South is considered a principal threat material. The pooled DNAPL recovery component will address this principal threat material and reduce the mass of COCs in the source area at Site I South.

Monitored Natural Attenuation – Natural attenuation refers to natural subsurface processes, such as advection, dispersion, sorption, and biodegradation, which result in reductions in the concentration and/or mass of COCs dissolved in groundwater. Natural attenuation processes are typically occurring at all sites, but to varying degrees of effectiveness depending on the types and concentrations of COCs present and the physical, chemical, and biological characteristics of the soil and groundwater.

Demonstrations of the effectiveness of natural attenuation typically involve long-term groundwater sampling and testing to evaluate COC concentrations over time and to determine if geochemical conditions are suitable for biodegradation of COCs. Microbiological data is also sometimes collected as evidence to support the occurrence of biodegradation. Section 6.3 summarizes available information regarding biodegradation of the indicator constituents in groundwater at Sauget Area 1. The report in Appendix G provides a more detailed evaluation of MNA at Sauget Area 1.

Groundwater Pump and Treat – This remedial technology includes pumping of groundwater from extraction wells followed by above ground treatment of the water using a treatment technology appropriate for the COCs that are present in the produced groundwater. Groundwater pump & treat technology can be used for hydraulic containment of a plume and/or removal of COC mass from the plume core. This technology can also be adapted for other uses such as leachate control at waste disposal sites.

Air Sparging with Soil Vapor Extraction – Air sparging involves the injection of atmospheric air into an aquifer through vertical or horizontal wells. This technology can remove COCs by volatilization as well as by in-situ aerobic biodegradation, due to the increased concentration of dissolved oxygen. Air sparging systems are coupled with soil vapor extraction (SVE) systems in situations where vapor migration could cause adverse impacts.

An SVE system removes gases from the unsaturated zone using a network of closely spaced extraction wells under vacuum pressure. The gases leaving the SVE system are typically treated using oxidation or granular activated carbon. If COC concentrations are low enough, the gases may be vented directly to the atmosphere, depending on local and state air discharge regulations.

Biosparging – Biosparging is a particular mode of air sparging operation that emphasizes aerobic biodegradation over volatilization. Biosparging systems are typically designed to operate without an SVE system. Air injection is controlled such that an SVE system and the associated vapor treatment equipment would not be required.

12.1.2 Discussion Regarding Bioventing

Bioventing involves delivery of air to unsaturated soils by extraction or injection to stimulate aerobic biodegradation of COCs such as benzene, chlorobenzene, and dichlorobenzenes. This technology only addresses the unsaturated zone, which is not the main source of COCs to groundwater at Sauget Area 1. Results of mass flux calculations for Sauget Area 1 indicate that mass flux of COCs to groundwater at Sauget Area 1 is primarily due to movement of the groundwater through residual DNAPL sources in the aquifer matrix beneath Sites G, H, and I South, and not from leaching of unsaturated source materials (see discussion in Section 6.2).

Bioventing of fill materials and unsaturated soils is not included in any of the potential alternative arrays for Sauget Area 1 due to the limited benefit of this technology for the Sauget Area 1 sites. However, treatment of the saturated zone by air sparging with SVE or by biosparging would result in some movement of air through the unsaturated zone, thus allowing some aerobic treatment to occur in the unsaturated fill materials and soil.

12.1.3 Discussion Regarding the Sauget Area 2 Groundwater Migration Control System

As discussed in Section 2.4, the Sauget Area 2 Groundwater Migration Control System (GCMS) includes a 3,300 ft long “U”-shaped, fully penetrating barrier wall located downgradient of Sauget Area 2 Site R and three groundwater extraction wells on the upgradient side of the barrier wall. The groundwater extraction wells have been in operation since July 2003, and construction of the barrier wall was completed in 2004.

The Sauget Area 2 GMCS was designed to abate adverse impacts on the Mississippi River resulting from the discharge of affected groundwater from the Sauget Area 2 sites, the Sauget

Area 1 sites, the southern portion of the W.G. Krummrich Facility, and other industries in the Sauget area.

The Sauget Area 2 GMCS does capture a portion of the mass flux from the Sauget Area 1 plumes, as discussed in Section 6.5 and summarized in Section 12.2.1. Thus, the GMCS does offer some benefit for Sauget Area 1 relative to the remedial action objective of preventing groundwater discharges to the River that result in unacceptable, adverse effects on the River. However, since the need to operate the Sauget Area 2 GMCS is largely based on the treatment needs of Sauget Area 2, the Sauget Area 2 GMCS is not included as a component in any of the potential alternative arrays developed for Sauget Area 1.

12.1.4 Development of Site-Specific Alternatives

Potential remedial alternatives developed for Sauget Area 1 are presented and summarized below. These alternatives address affected soil and waste, leachate, soil vapors, principal threat materials, and groundwater.

Potential Alternative	Components
Alternative 1	No action
Alternative 2	- Institutional Controls - Containment Cell Operation and Maintenance (O&M) – See Note below - Monitored Natural Attenuation (MNA)
Alternative 3	- Institutional Controls, Containment Cell O&M, MNA - Utility Relocation, Pooled DNAPL Recovery at BR-I - Capping Sites G, H, I South, and L
Alternative 4	- Institutional Controls, Containment Cell O&M, MNA - Utility Relocation, Pooled DNAPL Recovery at BR-I - Capping Sites G, H, I South, and L - Leachate Control at Sites G, H, and I South
Alternative 5	- Institutional Controls, Containment Cell O&M, MNA - Utility Relocation, Pooled DNAPL Recovery at BR-I - Soil or Crushed Rock Covers at Sites G, H, I South and L - Pulsed Air Biosparging at Residual DNAPL Areas at Sites G, H, and I South
Alternative 6	- Institutional Controls, Containment Cell O&M, MNA - Utility Relocation, Pooled DNAPL Recovery at BR-I - Soil or Crushed Rock Covers at Sites G, H, I South and L - Air Sparging with SVE at Residual DNAPL Areas at Sites G, H, and I South
Alternative 7	- Institutional Controls, Containment Cell O&M, MNA - Utility Relocation, Pooled DNAPL Recovery at BR-I - Capping Sites G, H, I South, and L - Hydraulic Containment Downgradient of Sites G, H, and I South

Potential Alternative	Components
Alternative 8	- Institutional Controls, Containment Cell O&M, MNA - Utility Relocation, Pooled DNAPL Recovery at BR-I - Capping Sites G, H, I South, and L - Groundwater Removal at Source Areas at Sites G, H, and I South - Hydraulic Containment Downgradient of Sites G, H, and I South
Alternative 9	- Institutional Controls, Containment Cell O&M, MNA - Utility Relocation, Pooled DNAPL Recovery at BR-I - Excavation and Off-Site Disposal of Wastes at Sites G, H, I South, and L

Note: There are currently plans to add PCB-affected soils (excavated at the W.G. Krummrich facility) to utilize unused Containment Cell capacity. After these soils are added the final engineered cover for the Containment Cell will be installed. Installation of the Containment Cell final cover is required by the May 31, 2000 Unilateral Administrative Order related to the sediment and soils removal action, and is not part of the Sauget Area 1 FS.

Alternative 1, the No Action alternative, does not involve any treatment, removal, or monitoring.

Alternative 2 includes institutional controls, Containment Cell O&M, and MNA.

The following five technologies are common to Alternatives 3 through 9: institutional controls; MNA; Containment Cell O&M; utility relocation; and pooled DNAPL recovery at well BR-I.

Alternative 3 includes the five common technologies listed above plus engineered covers consisting of RCRA Subtitle C caps for Sites G, H, I South, and L.

Alternative 4 includes the same components as Alternative 3 plus leachate recovery. Leachate recovery would be performed at a grid of leachate recovery wells screened in the fill and waste materials at Sites G, H, and I South. The recovered leachate would be treated on site and discharged to the American Bottoms Regional Treatment Facility.

Alternatives 5 and 6 include the five common technologies listed above plus a remedy component that provides source treatment in the areas of residual DNAPL in the MHU and DHU at Sites G, H, and I South. The source treatment technologies in these alternatives are pulsed air biosparging (Alternative 5) and continuous air sparging with soil vapor extraction (Alternative 6). Both technologies would involve installation of a grid of sparge wells screened in the MHU and DHU and vent wells screened in the fill and waste and upper few feet of the MHU. Vapors recovered from the pulsed air biosparging (PABS) system would be captured by passive vent wells and treated using drums of granular activated carbon. Vapors from the continuous air sparging system would be captured by an SVE system of closely spaced wells and treated using oxidation or granular activated carbon, depending on the vapor concentrations. A pilot test would be required for either alternative prior to full-scale implementation. The pilot test would be conducted to determine operational parameters, measure performance characteristics, and verify the optimal well spacing. Alternatives 5 and 6 include soil or crushed rock covers instead of RCRA Subtitle C caps.

Alternative 7 includes the same components as Alternative 3 plus hydraulic containment of the plume downgradient of Sites G, H, and I South. The hydraulic containment remedy component would involve installation and operation of groundwater extraction wells located at the downgradient edge of the Sauget Area 1 study area. As discussed in Section 12.3, hydraulic containment of the Sauget Area 1 plumes at the downgradient edge of the Sauget Area 1 study area would require installation of five groundwater extraction wells operating at 350 to 400 gpm each, with a total system flowrate of 1850 gpm. Extracted groundwater would be routed to the Sauget Physical/Chemical Wastewater Treatment Plant (the "PChem Plant") for preliminary and primary treatment and then to the American Bottoms Regional Wastewater Treatment Facility (the "American Bottoms Plant") for secondary treatment.

Alternative 8 includes the same components as Alternative 7 plus groundwater removal at the residual DNAPL areas at Sites G, H, and I South as a source removal / treatment component. This alternative would involve installation and operation of groundwater extraction wells located at the residual DNAPL source areas at Sites G, H, and I South and extraction wells located along the downgradient boundary edge of the Sauget Area 1 study area. For remedy screening purposes, it is assumed that a total of 8 high-capacity extraction wells would be installed, including three in the source areas and five along the downgradient edge of Sauget Area 1 and that the system would be operated at a total flowrate of 2,800 gpm, which is 50% higher than the flowrate for Alternative 7. Recovered groundwater would be routed to the PChem Plant for preliminary and primary treatment and then to the American Bottoms Plant for secondary treatment.

Alternative 9 includes the five common technologies listed above plus excavation and off-site disposal of wastes and fill materials at Sites G, H, I South, and L, with a total loose volume of approximately 827,000 cubic yards. The excavated areas would be backfilled with clean imported fill soil.

12.2 Discussion Regarding Monitored Natural Attenuation and Point of Compliance Monitoring Along the River

12.2.1 Evaluation of Monitored Natural Attenuation

Mass removal by natural attenuation in 2006 in the Sauget Area 1 plumes can be estimated based on the calculated mass flux in the MHU and DHU at the Site I source area as discussed in Section 6.2.1.3 and modeled mass flux (also called mass discharge) calculations using the groundwater fate and transport model, as discussed in Section 6.5.1. The results are summarized in the table below, which was presented in Section 6.5.2.

Calculated Mass Removal by Natural Attenuation for the Sauget Area 1 Plumes in 2006	
	Mass Flux (kg/yr)
A: Calculated Mass Flux from Site I Source Area *(GSI, 2005)*	**2,780**
B: Modeled Mass Flux To River in 2006 with GMCS On	**94**
C: Modeled Mass Flux Removed by GMCS in 2006	**142**
Estimated Mass Removal by Natural Attenuation in 2006 (= A - B - C)	**2,554**

As shown on the table above, in 2006 there was an estimated 2780 kg/yr of mass flux of COCs leaving the Sauget Area 1 source areas and an estimated 2554 kg/yr was removed by natural attenuation processes before reaching the area near the Mississippi River. Based on these estimates, natural attenuation processes cause an estimated 92% reduction in the mass flux of COCs in groundwater between the Sauget Area 1 source areas and the Mississippi River.

There is considerable uncertainty in these mass flux estimates. The key assumptions used in developing the groundwater flow and transport model are discussed in Section 6.4, in the groundwater modeling report (GSI, 2008b) and in the model update memorandum (GSI, 2012).

Section 6.3 presents a general discussion of natural attenuation processes and the potential for the biodegradation of the Sauget Area 1 indicator constituents. The Sauget Area 1 indicator constituents that are biodegradable under aerobic conditions include chlorobenzene, 1,4-dichlorbenzene, benzene, vinyl chloride, 4-chloroaniline, and 2,4-D.

Anaerobic biodegradation of 1,4-dichlorobenzene is well documented. Chlorobenzene and benzene are biodegradable in anaerobic environments, but the reaction rates are much slower than in aerobic environments. Anaerobic biodegradation of 2,4-D has not been extensively studied but is known to occur. Anaerobic degradation of 4-chloroaniline is limited.

Tetrachloethene and trichloroethene undergo reductive dechlorination in anaerobic environments but tend to be recalcitrant in aerobic environments. Cis-1,2-DCE is also relatively recalcitrant in aerobic environments.

The report in Appendix G, “Evaluation of Monitored Natural Attenuation,” provides a site-specific evaluation of MNA for Sauget Area 1 based on existing COC and geochemical data, groundwater fate and transport modeling, and mass flux calculations.

Source remediation technologies that introduce air into the Alluvial Aquifer (i.e., air sparging or pulsed air biosparging) would remove volatile constituents but would also increase the concentration of dissolved oxygen in the aquifer and facilitate aerobic biodegradation of the indicator constituents that can degrade aerobically.

12.2.2 Conceptual Groundwater Monitoring Program for MNA

An MNA response action would require installation and monitoring of a network of wells screened in the SHU, MHU, and DHU at the Sauget Area 1 source areas and at upgradient and downgradient locations. The number and location of wells in the groundwater monitoring network would be established during the remedial design phase. Section 13.3.1 and Appendix G discuss a conceptual groundwater monitoring program for evaluating the performance of MNA at Sauget Area 1.

12.2.3 Conceptual Point of Compliance Locations along the River

Based on Illinois ARARs for landfill closures, point of compliance (POC) wells for Sauget Area 1 are needed along the River, since Illinois Class I groundwater standards will eventually need to be met in that area. The POC wells would also be used as sentinel wells to monitor the concentrations of site constituents discharging to the River.

Groundwater fate and transport modeling results indicate that the mass flux from the Sauget Area 1 sources to the Mississippi River is a relatively small percentage of the mass flux to the River from non-Sauget Area 1 sources. As discussed in Section 6.5.1, modeled mass flux results indicate that for all seven modeled COCs, the modeled mass flux to the Mississippi River from the Sauget Area 1 plumes in 2006 was 236 kg/year with the GMCS off and 94 kg/year with the GMCS on. To the extent that it occurs, the mass flux to the River from the Sauget Area 1 plumes would occur north of the barrier wall. Plumes originating from other sources (i.e., Sauget Area 2 and the Krummrich facility) also impact the groundwater north of the barrier wall along the River.

The number and location of POC wells along the River for the Sauget Area 1 plumes would be established during the remedial design phase. Conceptually, monitoring wells BSA-MW-5D and CPA-MW-5D could be suitable locations for POC wells for the Sauget Area 1 plumes (see well locations on Figure 10-5). These wells, which are located 1200 feet north and 2400 feet north of the barrier wall, respectively, are already included in the groundwater monitoring program for the Krummrich facility.

Appendix B provides a tabulation of all available groundwater monitoring data for BSA-MW-5D and CPA-MW-5D. Appendix B also includes a summary table that lists all VOCs and SVOCs that have been detected in these wells, the mean concentrations in each well, the Illinois Class I groundwater standards or other groundwater screening levels, and the aquatic life criteria for surface water.

12.3 Evaluation of Hydraulic Containment for Sauget Area 1 Plumes

Alternative 7 includes groundwater extraction at the downgradient boundary of the Sauget Area 1 study area for hydraulic containment of the Sauget Area 1 plumes. To evaluate this alternative, groundwater pumping simulations were performed using the regional groundwater flow and transport model to evaluate the number of extraction wells and flow rate required to cut off the Sauget Area 1 plumes at the downgradient boundary of the Sauget Area 1 study area. The chlorobenzene plume, which is the largest of the Sauget Area 1 plumes, was used in the analysis. The groundwater pumping simulations are documented in Appendix H.

The modeled extraction wells were assumed to begin operation in 2015. Simulations were initially conducted using extraction wells located immediately east of Illinois Route 3. However, groundwater extraction from wells along Route 3 was unable to achieve hydraulic containment of the Sauget Area 1 chlorobenzene plume. Simulations were then conducted using wells located along the boundary between the Sauget Area 1 study area and the W.G. Krummrich facility. Model simulation results for wells along that boundary indicate that hydraulic containment of the Sauget Area 1 plumes could be achieved using five groundwater extraction wells operating at a combined flowrate of 1850 gpm. The locations of the modeled extraction wells are shown on Figure 1 in Appendix H. The modeled extraction wells would capture the portion of the Sauget Area 1 plume that is located between the residual DNAPL source areas at Sites G, H, and I South and the southern boundary of the W.G. Krummrich facility.

The modeled extraction wells would cut off the portion of the Sauget Area 1 plume located between the modeled extraction wells and the River. If only Sauget Area 1 sources were active, then concentrations in this portion of the Sauget Area 1 plume would attenuate to MCLs relatively quickly, assuming that the modeled extraction wells continued operating. However, the Sauget Area 1 sources are not the only active sources. There are source areas at the Krummrich facility and at Sauget Area 2 that would result in continued impacts to groundwater in the area between the modeled extraction wells and the River.

The groundwater extraction system would have a high annual cost and would have to continue operating for hundreds of years to maintain hydraulic containment of the groundwater between the residual DNAPL source areas and the line of modeled extraction wells along the southern boundary of the W.G. Krummrich facility. The groundwater treatment fees would include an estimated $1.50 per 1,000 gallons at the PChem Plant and an estimated $3.74 per 1,000 gallons at the American Bottoms Plant, for a total treatment fee of approximately $5.24 per 1,000 gallons. Based on a flowrate of 1850 gpm, the annual cost for water treatment would be approximately $5.1 million per year. Overall, the O&M cost for Alternative 7 would be approximately **$5.5 million per year.**

The major capital costs for Alternative 7 include installation of groundwater extraction wells and pumps, installation of a pipeline to route the water to the sewer line, installation of caps at Sites G, H, I South, and L, relocation of phone, water, and fuel lines, and installation of monitoring wells. Appendix H includes a worksheet that lists all estimated capital costs, O&M costs (including treatment fees), and a calculation of present value costs. The estimated present value cost for Alternative 7 for 30 years of operation is **$78.9 million.**

Alternative 8 is similar to Alternative 7 but includes three additional extraction wells at Sites G, H, and I South, and an overall flowrate of 2,800 gpm. Based on the treatment fee of $5.24 per 1,000 gallons, the annual cost for water treatment would be approximately $7.7 million per year. Overall, the O&M cost for Alternative 8 would be approximately **$8.2 million per year.**

Appendix H includes a worksheet for Alternative 8 that lists all estimated capital costs, O&M costs (including treatment fees), and a calculation of present value costs. The estimated present value cost for Alternative 8 for 30 years of operation is **$113 million.**

12.4 Discussion Regarding Time to Clean Estimates

The technical memorandum in Appendix D provides a time to clean evaluation for the MHU and DHU for two key COCs, chlorobenzene and 1,4-dichlorobenzene. The regional groundwater flow and transport model was used to develop the time to clean estimates for a hypothetical monitoring well located 2300 ft downgradient of Site I South, approximately halfway between the Sauget Area 1 sources and the Mississippi River. Time to clean (i.e., time to reach the MCLs) was estimated for four scenarios: i) MNA alone; ii) 50% source mass reduction in year 2015 plus MNA; iii) 75% source mass reduction in 2015 plus MNA; iv) 90% source mass reduction in 2015 plus MNA. Source mass reduction could potentially be achieved by implementing a source treatment technology such as pulsed air biosparging (Alternative 5) or air sparging with SVE (Alternative 6). Source mass reduction could also be achieved by groundwater extraction in the Sauget Area 1 source areas and hydraulic containment at the downgradient boundary of the Sauget Area 1 study area (Alternative 8).

Calculated Results for Time to Clean in Years after 2015
(i.e., after date of source remediation)

	MNA Only (years after 2015)	MNA with 50% Source Reduction (years after 2015)	MNA with 75% Source Reduction (years after 2015)	MNA with 90% Source Reduction (years after 2015)
Chlorobenzene				
MHU	292	252	215	159
DHU	279	239	202	146
1,4-Dichlorobenzene				
MHU	169	127	85	30
DHU	172	130	88	33

There is considerable uncertainty in these calculated results. The following table shows the calculated results and the estimated range when an uncertainty factor of +/- 2 is applied for chlorobenzene in the MHU, which has the longest time to clean in the table above.

Time to Clean Estimates for Chlorobenzene in MHU

	Calculated Result (years from 2015)	Estimated Range (years from 2015)
MNA only	290	150-580
50% source mass reduction plus MNA	250	130-500
75% source mass reduction plus MNA	220	110-440
90% source mass reduction plus MNA	160	80-320

1) Estimates are rounded to nearest ten years.

As indicated on the table above, it will likely require on the order of >150 years to reach the MCL for chlorobenzene at the hypothetical monitoring well in the MHU even if source mass reduction is achieved by implementing a treatment technology.

Two Sauget Area 1 indicator constituents, benzene and 4-chloroaniline, were detected at concentrations exceeding regulatory levels in groundwater samples collected upgradient of the Sauget Area 1 source areas. As noted in Section 3.2.6.1, benzene was detected at a concentration of 6.55 ppb in the DHU upgradient of Sites G and H. As shown on Figures 5-22 and 5-43, benzene and 4-chloroaniline were detected at concentrations of 230 ppb and 4700 ppb, respectively, in the MHU upgradient of Site I South. These upgradient exceedances for benzene and 4-chloroaniline are not associated with Sauget Area 1 sources but contribute to the Sauget Area 1 plumes and could potentially result in increased time to achieve compliance with MCLs and Class I standards for benzene and 4-chloroaniline.

12.5 Discussion Regarding Why MCLs Can't Be Achieved within 50 to 100 Years

The time to clean estimates indicate that a 30-year time to clean is not feasible for the Sauget Area 1 plume. Monitored natural attenuation will ultimately restore groundwater quality downgradient of the Sauget Area 1 sites, but the time to achieve compliance with MCLs and Class I standards is in the range of several hundred years even if source mass reduction is achieved by implementing a treatment technology such as pulsed air biosparging (Alternative 5), air sparging with SVE (Alternative 6), or groundwater extraction in the source areas plus hydraulic containment (Alternative 8).

Source area treatments such as sparging (Alternative 5 and Alternative 6) may be capable of reducing the source area contaminant mass by an order of magnitude under optimal conditions. This 90% value was the upper bound for source mass reduction that was used in the time to clean estimates. While removing 90% of the mass may be accompanied by a similar (i.e., 90%) reduction in the groundwater concentration immediately downgradient of the source area, it does not result in a similar reduction in the time to clean, as summarized in Section 12.4. These results clearly demonstrate that the mass flux remaining following source treatment is still sufficiently high to sustain groundwater concentrations above the target criteria at Sauget Area 1 for over a hundred years.

Using groundwater extraction wells within the source areas (Alternative 8) may be able to significantly reduce mass flux from the source areas. However, this is only effective when the groundwater extraction system is operating, and it is unlikely that all mass would be removed during the conceptual 30-year operating period. The time to clean estimates demonstrate that the remaining mass would be sufficient to sustain groundwater concentrations above the target criteria for over a hundred years. Further, this alternative does not address the mass that has already migrated away from the source areas, which would not be removed until reaching the hydraulic contaminant wells at the downgradient boundary of the Sauget Area 1 study area. As with the source area extraction wells, these downgradient hydraulic containment wells are only effective when operating. As containment wells, they will not accelerate the time to clean the source areas or the portion of the plume located between the source areas and the containment wells. Furthermore, Alternative 8 has a very high cost. The estimated present value cost for Alternative 8 for 30 years of operation is $113 million.

12.6 Screening of Remedial Alternatives

The nine potential remedial alternatives presented above were screened on the basis of effectiveness, implementability, and relative cost, which were the same criteria used to screen out remedial technologies in Section 11. Table 12-1 documents the screening process for the nine alternatives.

Alternatives 1 through 5 are retained for detailed evaluation and are described in more detail in Section 13.0. Alternatives 6 through 9 were screened out from further consideration.

Alternative 6 (soil or crushed rock covers and air sparging with SVE) was screened out because it would have similar performance compared to Alternative 5 (PABS) but much higher cost and energy usage. The technical memorandum in Appendix C presents a planning-level comparison of the performance and cost of air sparging and PABS. The cost would be higher for Alternative 6 compared to Alternative 5 due to the need for continuous operation of the air sparging system as well as installation and operation of numerous closely spaced SVE wells and the associated vapor treatment system. The energy usage would be higher for Alternative 6 compared to Alternative 5 because the air compressors would be in continuous operation, whereas in Alternative 5 the compressors would be operated intermittently for pulsed sparging.

Monitoring and control of emissions would be important with either Alternative 6 or Alternative 5 and would be investigated during a pilot test. However, Alternative 6, which involves continuous sparging, would have a greater potential for unacceptable risks to indoor workers in nearby buildings compared to Alternative 5. The nearby buildings and their approximate distances from the closest probable locations for sparge well pairs include: Sauget Village Hall, 200 ft southeast; Cerro Flow Products, 150 ft west; Wiese Engineering building, 400 ft west; and Metro Construction Equipment, 150 ft east (relative to Site G).

As noted above, Alternative 5 is retained for detailed evaluation in Section 13 and Alternative 6 is screened out.

Alternatives 7 and 8 were screened out because Alternative 5 achieves source zone mass reduction at far less cost and does not require consumption of large quantities of electrical power and other resources to pump and treat groundwater for hundreds of years as would be required for Alternatives 7 and 8.

Alternative 7 (RCRA caps and hydraulic containment) includes 5 high-capacity extraction wells with a total flowrate of 1850 gpm. The estimated O&M cost for Alternative 7 is $5.5 million per year, and the estimated present value cost for Alternative 7, including capital costs and 30 years of operation, is $78.9 million.

Alternative 8 (RCRA caps, groundwater extraction in source areas, and hydraulic containment) includes 8 high-capacity extraction wells with a total flowrate of 2800 gpm. The estimated O&M cost for Alternative 8 is $8.2 million per year, and the estimated present value cost for Alternative 8, including capital costs and 30 years of operation, is $113 million.

Alternative 9 would involve excavation and off-site disposal of approximately 827,000 loose cubic yards of waste and affected soils from Sites G, H, I South, and L. This alternative was screened out because it would be very expensive and difficult to implement and would involve significant short-terms risks to workers and the community during implementation.

13.0 DETAILED EVALUATION OF ALTERNATIVES

This section presents the detailed evaluation of remedial action alternatives developed for Sauget Area 1 sites. The alternatives developed for evaluation are as follows:

Alternative	Components
Alternative 1	- No action
Alternative 2	- Institutional Controls - Containment Cell Operation and Maintenance (O&M) - Monitored Natural Attenuation (MNA)
Alternative 3	- Institutional Controls, Containment Cell O&M, MNA - Utility Relocation, Pooled DNAPL Recovery at BR-I - Capping Sites G, H, I South, and L
Alternative 4	- Institutional Controls, Containment Cell O&M, MNA - Utility Relocation, Pooled DNAPL Recovery at BR-I - Capping Sites G, H, I South, and L - Leachate Control at Sites G, H, and I South
Alternative 5	- Institutional Controls, Containment Cell O&M, MNA - Utility Relocation, Pooled DNAPL Recovery at BR-I - Soil or Crushed Rock Covers at Sites G, H, I South and L - Pulsed Air Biosparging at Residual DNAPL Areas at Sites G, H, and I South

The alternatives are evaluated on the basis of criteria outlined in the USEPA document "Guidance for Conducting Remedial Investigations and Feasibility Studies" (USEPA, 1988). The assessment criteria are listed and described in Section 13.1. Alternatives 1 through 5 are evaluated in Sections 13.2 through 13.6. A comparative analysis of the five alternatives is provided in Section 13.7.

13.1 CRITERIA FOR DETAILED EVALUATION OF THE ALTERNATIVES

Several evaluation criteria have been developed to support assessment of the various remedial alternatives and to support final selection of remedial actions. The evaluation criteria are outlined in FS guidance (USEPA, 1988) and include the following:

Threshold Criteria

Threshold criteria are the requirements that each alternative must meet in order to be eligible for selection. The two threshold criteria include:

- Overall protection of human health and the environment
- Compliance with ARARs

Balancing Criteria

Balancing criteria are used to compare relative effectiveness between alternatives so that the strengths and weaknesses of each alternative can be evaluated. The five balancing criteria include:

- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost

Modifying Criteria

The modifying criteria are State acceptance and community acceptance of the remedial option. USEPA will consider and address both State and community acceptance of an alternative when making a recommendation and in the final selection of a remedy. Consequently, these criteria are not addressed in this report.

The two threshold criteria and five balancing criteria are briefly described in the following paragraphs.

Overall Protection of Human Health and the Environment - The analysis of each alternative with respect to overall protection of human health and the environment evaluates how the alternative reduces or eliminates short-term and long-term risk by controlling or eliminating exposures to COCs at concentrations that may produce harmful effects. Concentrations of COCs must be controlled at or below levels resulting in the excess risk. Appropriate remedies control, eliminate or reduce risks posed by each exposure pathway through treatment, engineering or institutional controls.

Compliance with ARARs - This assessment criterion is used to determine whether each alternative will meet all of its federal and state ARARs, which are defined as the laws, rules, regulations, or standards that need to be considered during design or implementation of a remedy. Table 13-1 presents the classification of the ARARs and provides a demonstration of compliance as part of the detailed evaluation of remedial action alternatives.

Long-Term Effectiveness and Permanence - Long-term effectiveness and permanence are evaluated with regard to i) the magnitude of residual risk remaining after source containment and/or treatment are complete; and ii) the adequacy and reliability of controls, if any, that are used to manage treatment residuals or untreated wastes that remain at the site. The magnitude of residual risk of the remaining waste upon completion of remedial activities is based upon the persistence, toxicity, mobility of the residuals and their propensity to bio-accumulate. Adequacy and reliability of controls are considered under this criterion. Alternatives that address long-term effectiveness are those that maintain protection of human health and the environment after response objectives have been met.

Reduction of Toxicity, Mobility, or Volume through Treatment - The statutory preference is to select a remedy that uses treatment to permanently and significantly reduce the toxicity, mobility, or volume of the COCs. The detailed evaluation of the alternatives against this criterion assesses the performance of each alternative in achieving these goals. Relevant factors in this criterion include review of the specific treatment process the remedy will employ and the materials it will treat; the amount of hazardous materials that will be destroyed or treated, including how principal threats will be addressed; the degree of expected reduction in toxicity, mobility, or volume; and the degree to which treatment is used as a principal element of the alternative.

Short-Term Effectiveness - The short-term effectiveness criterion addresses the effects to human health and the environment that the alternative will have during construction and implementation. Some factors considered in this evaluation are protection of workers, risks to the community, environmental impacts, and time until RAOs are achieved.

Implementability - The analysis of implementability deals with the technical and administrative feasibility of implementing the alternatives, and the availability of the services and materials needed for implementing the alternative. Technical feasibility includes such issues as the technical difficulties and unknowns associated with construction and operation of the components of the alternatives; the likelihood of technical problems associated with implementation that will lead to schedule delays; and the ability to monitor the effectiveness of the remedy. Administrative feasibility pertains to obtaining permits or regulatory approval from other offices or agencies.

Cost - The cost analysis involves development of planning-level cost estimates for each alternative to provide an accuracy of minus 30% to plus 50%. The cost estimates for the Sauget Area 1 alternatives are presented in Appendix F. The estimates were developed using USEPA guidance (USEPA, 2000), vendor quotations, RACER cost estimating software, cost information from prior projects, and engineering judgment. Finally, a discount rate was used in calculating present worth costs for the Sauget Area 1 alternatives.

The cost estimates include capital and annual O&M costs. Capital costs include direct costs for construction of remedy components as well as indirect costs such as remedial design, project management, overhead, and implementation of institutional controls. Annual O&M costs include environmental sampling and testing and the O&M of any remediation equipment or systems that remain in operation after remedy construction is complete. A contingency was applied to capital costs and annual O&M costs based on the degree of uncertainty in the scope of work (due to incomplete design) and to account for construction contingency.

Sections 13.2 through 13.6 present the description and detailed evaluation of the five alternatives for the criteria listed above.

13.2 DESCRIPTION AND DETAILED EVALUATION OF ALTERNATIVE 1

Alternative 1 is a No Action alternative that is included for comparative purposes. It does not include any additional investigation, remediation, or monitoring.

Overall Protection of Human Health and the Environment - The No Action alternative does not include any measures to prevent potential exposures to affected soils or waste and therefore does not meet the RAOs. This alternative is not protective of human health and the environment.

Compliance with ARARs - This alternative does not satisfy ARARs.

Long-Term Effectiveness and Permanence - This alternative is not effective in the long term at meeting the RAOs.

Reduction of Toxicity, Mobility or Volume through Treatment - This alternative does not accomplish any reduction of toxicity, mobility, or volume of the COCs through treatment. Some reductions of COCs in groundwater will occur due to natural attenuation processes, but this alternative does not include any monitoring of plume conditions over time.

Short-Term Effectiveness - This alternative will not have any effects to human health and the environment or risks to the community during implementation because no technologies are implemented.

Implementability and Cost - This alternative is implementable since no remedial actions are required for this alternative. There is no cost associated with this alternative.

13.3 DESCRIPTION AND DETAILED EVALUATION OF ALTERNATIVE 2

13.3.1 Description of Alternative 2

Alternative 2 includes the following components:

- Institutional Controls
- Containment Cell O&M
- Monitored Natural Attenuation

Institutional Controls – Institutional controls, which are included as a remedy component in Alternatives 2, 3, 4, and 5, are designed to control access to the site, manage construction or other intrusive activities that may disturb soil or waste, and minimize potential exposure to COCs. Institutional controls that could be implemented include deed restrictions, zoning restrictions, and access restrictions such as fences or warning signs. A detailed description of the institutional controls for Sauget Area 1 will be developed in an Institutional Controls Implementation Plan to be prepared during the remedial design process.

As discussed in Section 10.3, Sites G, H, I South, and L are carried forward for active remediation in the FS, and all are considered as candidates for institutional controls. As discussed in Section 10.4, remediation of Dead Creek Segments A through F and the Borrow Pit Lake has been completed and, therefore, they are not carried forward for active remediation in the FS. The PRPs plan to voluntarily place institutional controls on Dead Creek Segments A and B.

There are municipal ordinances in place prohibiting use of groundwater as potable water in the Village of Sauget and the Village of Cahokia. Existing access restrictions at Sauget Area 1 include fencing and posting at Site G, at Site I (including Creek Segment A), and at Creek Segment B.

Additional access restrictions that could be established include installation of fences at Site H and Site L and a plan for the inspection and maintenance of the proposed fences at Site H and Site L and the existing fences at Site G and Site I (i.e., the fence at the Cerro Flow Products facility). Additional institutional controls that could be applied at Sites G, H, I South and L include the following: i) filing of deed notices or restrictions to limit future property uses to activities consistent with final closure measures, such as prohibiting disturbance of fill areas and prohibiting construction of new buildings on the fill areas without vapor controls; ii) filing of deed notices or restrictions to specify commercial/industrial land use; and iii) posting of information to describe required personal protective equipment (PPE) and monitoring for construction workers during any future excavation activities that may be necessary.

Containment Cell O&M - Containment Cell O&M is included in Alternatives 2, 3, 4, and 5. The existing Containment Cell is a RCRA and TSCA-compliant containment cell that was constructed in 2001 and is located immediately west of Creek Segment B and south of Site G. The materials that were placed in the Containment Cell included sediments and creek-bottom soils excavated from Dead Creek and the Borrow Pit Lake. There are currently plans to add PCB-affected soils (excavated at the W.G. Krummrich facility) to utilize unused Containment Cell capacity.

The required O&M of the Containment Cell is detailed in the Operation and Maintenance Plan (Golder, 2008). The O&M activities include the following: i) regular inspections of the cap; ii) sampling of primary and secondary leachate with analysis for pH, specific conductance, PCBs, and chlorinated VOCs; iii) collection and treatment of leachate; iv) quarterly sampling of treatment system effluent with analysis for VOCs, SVOCs, PCBs, and metals; v) quarterly sampling of selected monitoring wells with analysis for VOCs, PCBs, and metals; and vi) maintenance and repairs as needed (e.g., replacement or repair of pumps and mowing, fertilizing and re-seeding).

Monitored Natural Attenuation (MNA) - The MNA component is included in Alternatives 2, 3, 4, and 5. Natural attenuation refers to natural subsurface processes, such as advection, dispersion, sorption, and biodegradation, which result in reductions in the concentration and/or mass of COCs dissolved in groundwater. Natural attenuation processes are typically occurring at all sites, but to varying degrees of effectiveness depending on the types and concentrations of COCs present and the physical, chemical, and biological characteristics of the soil and groundwater.

Demonstrations of the effectiveness of natural attenuation typically involve long-term groundwater sampling and testing to evaluate COC concentrations over time and to determine if geochemical conditions are suitable for biodegradation of COCs. Microbiological data is also sometimes collected as evidence to support the occurrence of biodegradation. Sections 6.3 and 12.2.1 summarize available information regarding biodegradation of the indicator constituents in groundwater at Sauget Area 1, and the report in Appendix G provides a more detailed evaluation of MNA at Sauget Area 1.

Implementation of MNA at Sauget Area 1 would involve installation of a monitoring well network and periodic groundwater sampling and testing for VOCs, SVOCs, and selected geochemical parameters. The number and location of wells in the groundwater monitoring network will be established during the remedial design phase. The conceptual monitoring well network is shown on Figure 13-1 and includes well clusters at thirteen locations. Locations 1 through 8, which are upgradient or immediately downgradient of the fill areas, include wells screened in the SHU, MHU, and DHU. Locations 9 through 13, which are farther downgradient of the source areas, include wells screened in the MHU and DHU but not the SHU.

In addition, as discussed in Section 12.2.3, point of compliance (POC) wells will be placed along the Mississippi River to satisfy Illinois ARARs for landfill closures. The number and location of POC wells along the River for the Sauget Area 1 plumes would be established during the remedial design phase. Conceptually, monitoring wells BSA-MW-5D and CPA-MW-5D appear to be suitable locations for POC wells for the Sauget Area 1 plumes (see Figure 10-5). These wells are already included in the groundwater monitoring program for the Krummrich facility.

13.3.2 Detailed Evaluation of Alternative 2

Overall Protection of Human Health and the Environment - Alternative 2 does not include engineered covers (e.g., RCRA caps, soil covers, or crushed rock covers) or another remedy component to prevent potential exposure to COCs in surface soil, subsurface soil, or waste at Sites G, H, I South, and L. Therefore, Alternative 2 does not address the RAOs for surface soil, subsurface soil, waste, and/or leachate and does not provide overall long-term protection of human health and the environment for several relevant exposure pathways. Institutional controls alone are not considered sufficient to prevent potential exposure to soils or wastes at the sites with the possible exception of Site I South, which is located at an active industrial facility and has very little potential for the general public to be exposed to COCs.

Alternative 2 achieves the soil vapor RAO that calls for preventing unacceptable risks to indoor workers resulting from exposure to COCs found in soil vapor at the source areas. Results of the vapor intrusion HHRA summarized in Section 8 indicate that concentrations of COCs found in soil vapor at the source areas do not pose an unacceptable risk to human receptors in existing buildings located at or near the source areas. Alternative 2 includes institutional controls that will prevent construction of new buildings on the Sauget Area 1 source areas without vapor controls.
Alternative 2 meets the groundwater RAO that calls for preventing the ingestion of groundwater with COC concentrations exceeding MCLs and Class I standards. Groundwater is not used as a

source of drinking water in the area. There are some private wells (see Figure 2-27) that may be used for outdoor household activities, but none are located within or downgradient of the Sauget Area 1 groundwater plumes. The existing ordinances in the Villages of Sauget and Cahokia prohibiting the use of groundwater as a potable water source provide appropriate protection of human health.

Alternative 2 meets the groundwater RAO that calls for restoration of groundwater quality to MCLs and Illinois Class I drinking water standards, to the extent practicable. A 30-year time to clean is not feasible for the Sauget Area 1 plume. Based on time to clean calculations in Appendix D, groundwater quality will ultimately be restored through MNA processes alone, although the time to achieve compliance with MCLs and Class I standards downgradient of the Sauget Area 1 sites is in the range of several hundred years.

Alternative 2 addresses the groundwater RAO that requires preventing groundwater discharges to the Mississippi River from the Sauget Area 1 source areas that result in an unacceptable, adverse ecological impact to the River. As discussed in Section 6.5, the updated regional groundwater flow and transport model (GSI, 2012) was used to quantify the mass flux to the Mississippi River from the Sauget Area 1 plumes with the GMCS off and with the GMCS on for seven COCs (i.e., chlorobenzene; 1,4-dichlorobenzene; PCE; TCE; 1,2-DCE; vinyl chloride; and 2,4-D). Modeled mass flux results for the year 2020 and beyond indicate that, for all 7 COCs, the GMCS will capture approximately 73% of the modeled mass flux from Sauget Area 1 that reaches the area near the Mississippi River. To the extent that it occurs, the mass flux to the River from the Sauget Area 1 plumes would be located north of the barrier wall in an area that is within the plume areas from other sources, including Sauget Area 2 and the Krummrich plant. Groundwater concentrations along the River north of the barrier wall can be monitored for the Sauget Area 1 COCs using two conceptual point-of-compliance well locations discussed in Section 12.2.3.

Compliance with ARARs – The ARARs identified for the Sauget Area 1 remedial alternatives are listed in Table 13-1. The table also provides the classification for each ARAR, the rationale for the classification, and a discussion regarding compliance with the ARAR.

ARARs that govern the closure and post-closure requirements related to landfills include 35 IAC 807, which contains the standards for solid waste landfills, and 35 IAC 724, which contains the standards for owners and operators of hazardous waste treatment, storage and disposal facilities. Alternative 2 does not satisfy identified relevant and appropriate ARARs for soil and waste due to the absence of an engineered cover or other technology to prevent potential exposure to affected soils and wastes present in the fill areas at Sites G, H, I South, and L.

Alternative 2 satisfies ARARs relating to groundwater quality standards. One of the ARARs relating to groundwater quality is in 35 IAC 620.405, which prohibits a person from causing, threatening, or allowing release of contaminants to groundwater resulting in exceedance of groundwater quality standards. Another ARAR related to groundwater quality standards is 35 IAC 620.410, which contains the Illinois Class 1 groundwater standards. Alternative 2 meets the requirements of 35 IAC 620.405 and 35 IAC 620.410. At the end of the remedial action for Alternative 2 there will not be releases of COCs to groundwater that would result in exceedances of groundwater quality standards, and the Class I groundwater standards would be met by Monitored Natural Attenuation (MNA).

Alternative 2 also satisfies various ARARs that address the requirements for groundwater monitoring by owners and operators of hazardous waste disposal facilities. These ARARs include 35 IAC 724.191 through 35 IAC 724.197 and 35 IAC 724.199. The substantive requirements of these ARARs will be met for Alternative 2 by the MNA groundwater monitoring program and by groundwater monitoring of point-of-compliance wells located along the Mississippi River.

Long-Term Effectiveness and Permanence - Alternative 2 does not address the RAOs for soil waste, and/or leachate at Sites G, H, I South, and L and does not reduce the risks to potential human receptors at those areas. Institutional controls alone are not considered sufficient to prevent potential exposure to soils or wastes at any of the sites with the possible exception of Site I South, which is located at an active industrial facility and has very little potential for the general public to be exposed to COCs.

Alternative 2 addresses the three RAOs for groundwater, although the time to achieve MCLs or Illinois Class I standards will likely be several hundred years.

Reduction of Toxicity, Mobility or Volume through Treatment - Alternative 2 does not include treatment of soil, waste, or leachate within the fill areas and does not include treatment of residual DNAPL within the MHU and DHU or pooled DNAPL at well BR-I. In the long term, Alternative 2 reduces the toxicity and volume of the COCs in groundwater by monitored natural attenuation.

Short-Term Effectiveness - Short-term risks associated with implementation of Alternative 2 are minimal. Implementation of Alternative 2 involves installation and sampling of monitoring wells and performance of routine O&M activities at the Containment Cell. These actions will not involve any significant risks to the community. The potential risks to site workers (i.e., drilling crew and sampling technicians) can be managed by requiring adequate PPE and routine safety procedures that will be specified in a health and safety plan to be developed during remedial design.

Implementability - Alternative 2 is readily implementable. Institutional controls are common and easily implementable. Construction of monitoring wells and performance of Containment Cell O&M activities are implementable at the site using locally available resources and equipment. Monitoring the performance of these technologies is technically feasible.

Cost - The estimated present value cost for Alternative 2 is **$3.1 million.** Table F-2 presents a summary of capital costs, O&M costs, and a calculation of present value costs for Alternative 2.

13.4 DESCRIPTION AND DETAILED EVALUATION OF ALTERNATIVE 3

13.4.1 Description of Alternative 3

Alternative 3 includes the following components:

- Institutional Controls
- Containment Cell O&M
- Monitored Natural Attenuation
- Utility relocation
- Pooled DNAPL Recovery at BR-I
- Capping Site G, Site H, Site I South, and Site L

Institutional controls, Containment Cell O&M, and monitored natural attenuation were described under Alternative 2 in Section 13.3. The additional components of Alternative 3 are described below.

Utility Relocation - This component is in Alternatives 3, 4, and 5 and includes the following: i) relocation of a water supply line that runs through Site I South to the Sauget Village Hall; ii) relocation of a 14-inch diameter fuel pipeline that is located in the utility corridor along Queeny Avenue adjacent to Site H; and iii) relocation of a buried telephone cable located in the utility corridor along Queeny Avenue adjacent to Site H. The replacement water line and fuel pipeline will be placed along alternative corridors routed around the fill areas. The replacement telephone line will either be placed along an alternative corridor routed around the fill areas or installed on overhead poles.

Relocation of these utilities will prevent utility workers from potentially coming into contact with wastes in Site I South and the principal threat waste that was encountered in the utility corridor adjacent to Site H. Relocation of the utilities will also prevent future disturbance of the engineered caps to be installed at Site I South and Site H. Preventing disturbance of the engineered caps is required to meet ARARs.

Pooled DNAPL Recovery at BR-I - Pooled DNAPL recovery at BR-I is included in Alternatives 3, 4, and 5 and has been performed on an every-other-week schedule since November 2008. BR-I is screened in bedrock and has a low yield (Figure 13-2). It is equipped with an electric-powered Blackhawk piston pump and control panel. A 500-gallon dual-wall poly tank is located adjacent to BR-I for storage of produced fluids. DNAPL is recovered by activating the piston pump and evacuating DNAPL and water until the pump discharge rate slows substantially, indicating that the well has effectively gone dry. Electric power is not available at BR-I, so a portable generator is used to activate the pump. A two-week period of more frequent DNAPL pumping conducted in June 2009 indicated that a DNAPL recovery rate of up to 2 to 3 gallons per day could possibly be achieved, at least initially.

Implementation of this remedy component will involve bringing power to BR-I, programming the pump controller for automated operation, and obtaining a larger tank for storage of the recovered fluids. Initially, the pump will be operated once per day. When the rate of DNAPL recovery has diminished sufficiently that daily operation appears to have limited effectiveness, the pump will be operated twice per week. When the rate of DNAPL recovery has diminished sufficiently, the pump will be activated once per week. When recovery using the weekly schedule has reached its limit of effectiveness, the DNAPL removal will be conducted once per month. When the limit of practicable recovery has been reached, the DNAPL recovery will be discontinued. Fluid levels will be monitored at BR-I and at a nearby well A1-19. Recovered DNAPL and water will be transported to an approved off-site facility for incineration.

The extent of pooled DNAPL in bedrock in the area surrounding BR-I should be investigated during the remedial design phase of the project. Recovery of pooled DNAPL from additional bedrock wells in the area near BR-I should be performed if they are productive based on results of this investigation.

Capping of Sites G, H, I South, and L– Capping of Sites G, H, I South, and L is included as a component of Alternatives 3 and 4. This component involves installation of low-permeability caps whose designs will vary depending on the current and future uses of the sites. Capping mitigates the potential for direct contact with or release of waste at these sites, mitigates the potential for leachate generation where leachable waste is present in the unsaturated zone, and mitigates the potential for leachate from the unsaturated zone to continue to contaminate underlying groundwater above numerical standards specified in ARARs.

At Site G, a RCRA Subtitle C cover would be installed at the northern portion of the fenced area as shown on Figure 13-3. The conceptual footprint of the RCRA Subtitle C cover within the fenced area corresponds to the approximate extent of waste and fill based on boundary trenching conducted during the RI. Waste was not found in the southern portion of the fenced area at Site G, and therefore the cap does not cover that area. The cross section of the RCRA Subtitle C cover for Site G is shown on Figure 13-5 and includes a low permeability layer underlain by a gas collection layer, and overlain by a drainage layer and protective soil cover and vegetative layer. The minimum slope of 2% provides for surface water drainage. Unclassified fill will need to be placed on top of the waste to achieve the required contours. At Site G West, asphalt pavement would be installed to cap the parking area surrounding the Wiese Engineering building. The new asphalt pavement surrounding the Wiese building would include a flexible membrane liner to be consistent with RCRA Subtitle C liner requirements.

At Site H, which is an undeveloped property, capping would involve installation of a RCRA Subtitle C cover for the entire area of Site H as shown on Figure 13-3. The conceptual cross section is shown on Figure 13-5.

Site I South is located at an active industrial facility, Cerro Flow Products. Site I South is used for truck trailer parking and has two plant roads, a rail spur, truck scales, and a guard shack within its boundary (see Figure 13-4). In addition, the eastern side of Cerro's employee parking lot is located within the boundary of Site I South. The site is covered by clean, purchased stone or surplus concrete that was placed to fill depressions and maintain grades for truck trailer parking.

The RCRA Subtitle C cover at Site I South would need to incorporate the existing features of the site (e.g., truck scale and guard shack). New asphalt pavement would need to be installed at the portion of the employee parking lot where the cap is located. The new asphalt pavement would include a flexible membrane liner to be consistent with RCRA Subtitle C liner requirements. Considering the present and future use of Site I South for truck trailer parking, the final surface layer would be crushed rock instead of a protective soil cover and vegetated layer. Figure 13-4 illustrates the conceptual cover area and Figure 13-6 depicts conceptual cross section of the RCRA Subtitle C cover at Site I South.

At Site L, capping would involve installation of a RCRA Subtitle C cover at an area immediately east of Dead Creek Segment B, as shown on Figure 13-3. Figure 13-5 shows the conceptual cross section for the RCRA Subtitle C cover at Site L.

The cap designs for Sites G, H, I South, and L would need to provide for the management of stormwater runoff. This issue would be addressed during remedial design.

13.4.2 Estimated Mass of Sauget Area 1 COCs Removed by DNAPL Pumping at BR-I

The mass of key COCs removed by pumping DNAPL at BR-I can be estimated based on the specific gravity and chemical composition of the DNAPL and the average DNAPL pumping rate. During the DNAPL characterization and remediation study a sample of the pooled DNAPL from BR-I was found to have a specific gravity of 1.42. Extensive testing was conducted to determine the chemical composition of the BR-I DNAPL (see Appendix C.2 of GSI, 2006c).

As discussed in Section 13.4.1, implementation of pooled DNAPL recovery at BR-I would initially involve automated pumping of the well once per day. When the rate of DNAPL recovery has diminished sufficiently that daily operation appears to have limited effectiveness, the pump will be operated twice per week, followed by reductions to once per week and once per month, as the rate of DNAPL recovery continues to diminish.

As discussed in Section 4.2.2.2, pumping of BR-I every other day for two weeks in June 2009 resulted in an average recovery of 2.9 gallons of DNAPL per event. However, this recovery rate would likely diminish during daily pumping over a longer time frame. Therefore, an assumed pumping rate of one gallon of DNAPL per day was used to estimate the mass of Sauget Area 1 COCs that would be removed by pooled DNAPL recovery at BR-I for one year.

The following table lists the weight fractions of the key COCs in the DNAPL and the calculated mass of the COCs that would be removed by DNAPL pumping at an assumed rate of one gallon of DNAPL per day for one year.

Estimated Mass of Key COCs in DNAPL Pumped from Well BR-I

	Weight Fraction of COC in Sample of BR-I DNAPL	Calculated Mass of COC in One Gallon of DNAPL (kg)	Calculated Mass of COC in 365 Gallons of DNAPL (kg)
Chlorobenzene	0.022 %	0.00118	0.43
1,4-Dichlorobenzene	0.84 %	0.0451	16.5
Benzene	0.0019 %	0.000102	0.037
1,2,4-Trichlorobenzene	14 %	0.752	274.6

If the average pumping rate at BR-I is one gallon of DNAPL per day, then the estimated masses of chlorobenzene, 1,4-dichlorobenzene, and benzene that would be recovered during one year of pumping are 0.43 kg, 16.5 kg, and 0.037 kg, respectively.

1,2,4-trichlorobenzene is not one of the indicator COCs for Sauget Area 1. However, 1,2,4-trichlorobenzene was included in the above table because it is the predominant COC in the BR-I DNAPL by weight fraction (14%), and it is known to biodegrade to form dichlorobenzenes. As shown in the table, an estimated 274.6 kg of 1,2,4-trichlorobenzene would be recovered by daily pumping of one gallon of DNAPL for one year.

13.4.3 Discussion Regarding the Limited Benefits of RCRA Subtitle C Covers

Installation of RCRA Subtitle C covers at Sites G, H, and I South would reduce the potential mobility of COCs in soil and waste by reducing infiltration of rainwater through the fill areas. However, reducing the infiltration of rainwater through the fill areas (and the associated mass flux from source materials in the unsaturated zone) will not reduce the mass flux due to lateral groundwater flow in the MHU and DHU and will therefore have no significant effect on time to restore groundwater quality downgradient of the Sauget Area 1 source areas.

Section 6.2 summarized the results of mass flux calculations at the Sauget Area 1 source areas that were presented in a previous technical memorandum (GSI, 2005). The calculations estimated the mass flux of chlorobenzene, 1,4-dichlorobenzene, and benzene due to i) groundwater flushing in the Alluvial Aquifer beneath Site I; ii) leaching of unsaturated source zone materials prior to installation of a low permeability cover; and iii) leaching of unsaturated source zone materials after installation of a low permeability cover.

The overall results of the 2005 mass flux estimates are shown on Figures 6-46 and 6-47 and summarized on the tables below. As indicated in the tables below, the mass flux of COCs from the unsaturated source materials, with or without a low permeability cover, is very small compared to the mass flux of COCs due to lateral groundwater flow through the MHU and DHU.

ESTIMATED MASS FLUX AT SITE I SOURCE ZONE ASSUMING A CRUSHED ROCK COVER AND A 19-ACRE SOURCE ZONE			
	Mass Flux due to Leaching from Unsaturated Source Materials (kg/yr)	**Mass Flux due to Lateral Groundwater Flow in MHU and DHU (kg/yr)**	**(Mass Flux from Leaching) / (Mass Flux from Lateral GW Flow)**
Chlorobenzene	**17**	**1,741**	**1.0%**
1,4-Dichlorobenzene	**16**	**1,026**	**1.5%**
Benzene	**2.0**	**12.8**	**15.6%**

ESTIMATED MASS FLUX AT SITE I SOURCE ZONE ASSUMING A RCRA CAP AND A 19-ACRE SOURCE ZONE			
	Mass Flux due to Leaching from Unsaturated Source Materials (kg/yr)	**Mass Flux due to Lateral Groundwater Flow in MHU and DHU (kg/yr)**	**(Mass Flux from Leaching) / (Mass Flux from Lateral GW Flow)**
Chlorobenzene	**0.02**	**1,741**	**0.001%**
1,4-Dichlorobenzene	**0.02**	**1,026**	**0.002%**
Benzene	**0.002**	**12.8**	**0.018%**

The calculations were performed for Site I South, which has the largest surface area of the four sites and generally has the highest concentrations of COCs. Therefore, the conclusions from the mass flux estimates are also considered applicable to the other sites.

Installing RCRA Subtitle C covers at Sites G, H, and I South, with or without leachate control, would have no significant effect on time to achieve MCLs and Class I standards in groundwater downgradient of the Sauget Area 1 source areas. This finding is relevant to the detailed evaluation of Alternative 3, which includes RCRA Subtitle C covers, and also to the detailed evaluation of Alternative 4, which includes RCRA Subtitle C covers and leachate control.

RCRA Subtitle C covers would not be appropriate for Alternative 5, which includes pulsed air biosparging. The soil or crushed rock or covers included in Alternative 5 are more appropriate to site conditions since they would allow some air movement through the waste.

13.4.4 Detailed Evaluation of Alternative 3

Overall Protection of Human Health and the Environment - Alternative 3 is protective of human health and the environment. It addresses all of the potential risks to human receptors identified in the HHRA.

The engineered covers in Alternative 3 include RCRA Subtitle C covers at Sites G, H, I South, and L and asphalt pavement at Site G West. These engineered covers, in conjunction with institutional controls, address the RAO for surface and subsurface soil and the RAO for waste and leachate by minimizing the potential for human exposure to COCs in those media.

Alternative 3 also achieves the soil vapor RAO. Results of the vapor intrusion HHRA indicate that concentrations of COCs found in soil vapor do not pose an unacceptable risk to human receptors in existing buildings, and Alternative 3 includes institutional controls that will prevent construction of new buildings on the source areas without vapor control.

Alternative 3 meets all three groundwater RAOs. Groundwater is not used as a source of drinking water in the area. Although there are some private wells that may be used for outdoor household activities, none are located within or downgradient of the Sauget Area 1 groundwater plumes. The existing ordinances in the Villages of Sauget and Cahokia prohibiting the use of groundwater as a potable water source provide appropriate protection of human health.

As discussed in Section 12.2, a 30-year time to clean is not feasible for the Sauget Area 1 plume. Based on time to clean calculations in Appendix D, groundwater quality will ultimately be restored through MNA, although the time to achieve compliance with MCLs and Class I standards downgradient of the Sauget Area 1 sites is in the range of several hundred years.

Alternative 3 addresses the groundwater RAO that requires preventing groundwater discharges to the Mississippi River from the Sauget Area 1 source areas that result in an unacceptable, adverse ecological impact to the River. As discussed in Section 6.5, the updated regional groundwater flow and transport model (GSI, 2012) was used to quantify the mass flux to the Mississippi River from the Sauget Area 1 plumes with the GMCS off and with the GMCS on. Modeled mass flux results for the year 2020 and beyond indicate that, for all 7 COCs, the GMCS will capture approximately 73% of the modeled mass flux from Sauget Area 1 that reaches the area near the Mississippi River. To the extent that it occurs, the mass flux to the River from the Sauget Area 1 plumes would be located north of the barrier wall in an area that is within the plume areas from other sources, including Sauget Area 2 and the Krummrich plant. Groundwater concentrations along the River north of the barrier wall can be monitored for the Sauget Area 1 COCs using two conceptual point-of-compliance well locations discussed in Section 12.2.3.

Compliance with ARARs - The ARARs identified for the Sauget Area 1 remedial alternatives are listed in Table 13-1. ARARs that govern the closure and post-closure requirements related to landfills include 35 IAC 807, which contains the standards for solid waste landfills, and 35 IAC 724, which contains the standards for owners and operators of hazardous waste treatment, storage and disposal facilities. Although the 35 IAC 807 standards are relevant to Sauget Area 1, they are not appropriate because the hazardous waste landfill requirements of 35 IAC 724 are better suited to site conditions. The engineered covers included in Alternative 3 satisfy identified ARARs for soil and waste present in the fill areas at Sites G, H, I South, and L.

The closure and post-closure care requirements in 35 IAC 724.410a defines the following minimum requirements for hazardous waste landfill covers:

1) Provide long-term minimization of migration of liquids through the closed landfill
2) Function with minimal maintenance
3) Promote drainage and minimize erosion or abrasion of the cover
4) Accommodate settling and subsidence so that the cover's integrity is maintained

Items 2 through 4 are relevant and appropriate for Sauget Area 1. Item 1 is relevant but not appropriate to site conditions. The caps included in Alternative 3 either comply with or are substantially equivalent to items 2 through 4.

The caps in Alternative 3 would provide long-term minimization of migration of liquids through the fill areas. However, long-term minimization of migration of liquids through the fill areas is not appropriate for Sauget Area 1 based on the following factors:

- Results from a mass flux evaluation of Site I indicates that estimated mass flux of key COCs from leaching of unsaturated source materials is small compared to estimated mass flux of the COCs due to lateral groundwater flow. (For detailed discussion of the mass flux evaluation see Section 13.4.3.)
- Average estimated waste thicknesses at Sites G, H, and I South are 20 ft, 20 ft, and 25 ft, respectively. Under typical conditions the lower portion of the waste at these sites is below the water table, and the water table can fluctuate by several feet over time based on measurements in monitoring wells near the Judith Lane Containment Cell. Installation of caps to minimize infiltration of rainwater at Sauget Area 1 would not address flushing effects from the rising and falling water table.
- No principal threat liquids or mobile source materials were identified in the wastes above the water table at the Sauget Area 1 sites.
- Impacted groundwater at Sauget Area 1 is addressed by MNA and the Sauget Area 2 GMCS.

Alternative 3 provides a closure which either complies with or meets the substantive requirements of 35 IAC 724.211(b), which requires that the closure controls, minimizes, or eliminates to the extent necessary to adequately protect human health and the environment, post-closure escape of hazardous waste, hazardous constituents, leachate, contaminated runoff, or hazardous decomposition products to the ground or surface waters or to the atmosphere.

The caps in Alternative 3 can be constructed to require minimal maintenance, which meets the substantive requirement of 35 IAC 724.211(a). Periodic maintenance as described in the O&M Plan would be implemented to correct any settling or subsidence and to facilitate any needed repairs to the caps.

Alternative 3 satisfies ARARs relating to groundwater quality standards, including 35 IAC 620.405, which prohibits a person from causing, threatening, or allowing release of contaminants to groundwater resulting in exceedance of groundwater quality standards, and 35 IAC 620.410, which contains the Illinois Class 1 groundwater standards. At the end of the remedial action for Alternative 3 there will not be releases of COCs to groundwater that would result in exceedances of groundwater quality standards, and the Class I groundwater standards would be met by MNA.

Alternative 3 also satisfies various ARARs that address the requirements for groundwater monitoring by owners and operators of hazardous waste disposal facilities. These ARARs include 35 IAC 724.191 through 35 IAC 724.197 and 35 IAC 724.199. The substantive requirements of these ARARs will be met for Alternative 3 by the MNA groundwater monitoring program and by groundwater monitoring of point-of-compliance wells located along the Mississippi River.

Long-Term Effectiveness and Permanence - Alternative 3 is an effective, permanent remedial approach that meets the RAOs for Sauget Area 1. The residual risk at Sauget Area 1 following implementation of Alternative 3 is small since the potential for exposure to COCs in soils and waste is significantly reduced. Installation of the engineered covers would be effective at minimizing the potential for human exposure to the soil, waste, and leachate and at preventing erosion of the fill areas. Alternative 3 addresses the three RAOs for groundwater, although the time to achieve MCLs or Illinois Class I standards will likely be several hundred years.

The institutional controls will remain in place permanently. The engineered covers, including the Containment Cell, will require long-term maintenance to ensure their effectiveness. The DNAPL recovery system at BR-I will also require long-term maintenance as long as this well continues to produce DNAPL.

Reduction of Toxicity, Mobility or Volume through Treatment - Alternative 3 includes recovery of pooled DNAPL at well BR-I and off-site incineration of the DNAPL at an approved TSD facility. This remedy component will reduce the volume of pooled DNAPL at well BR-I, thereby removing source mass and addressing this principal threat material. As discussed in Section 13.4.2, daily removal of one gallon of DNAPL from BR-I for one year would result in removal of approximately 0.43 kg of chlorobenzene; 16.5 kg of 1,4-dichlorobenzene; 0.037 kg of benzene; and 275 kg of 1,2,4-trichlorobenzene.

Alternative 3 does not include treatment of soil, waste, or leachate within the fill areas and does not include treatment of residual DNAPL within the MHU and DHU. In the long term, Alternative 3 reduces the toxicity and volume of the COCs in groundwater by monitored natural attenuation.

Short-Term Effectiveness - Short-term risks associated with implementation of Alternative 3 are typical of a construction project that involves construction of engineered covers. These risks include general risks to construction workers as well as risks to the community due to significant truck traffic needed to bring the large volume of fill and cover material to Sites G, H, I South, and L. Other risks include the potential for dust emissions or stormwater runoff from areas of affected soils or waste during construction of the cover.

The potential risks to the community due to dust emissions and stormwater runoff can be managed through measures that will be developed during remedial design. The potential risks to site workers during remedy implementation can be managed by requiring adequate PPE and routine safety procedures that will be specified in a health and safety plan to be developed during remedial design.

Alternative 3 would require an estimated 140,600 cubic yards of fill material and soil to be transported to the sites, which would require >7,000 truck loads and would result in the release of approximately 234,000 pounds of carbon dioxide to the atmosphere (Table 13-2).

Implementability – Alternative 3 could be implemented at Sites G, H, and L. However, Site I South is located at the Cerro Flow Products property, which is an active industrial facility and construction of a RCRA Subtitle C cover at Site I South would be difficult to implement and disruptive to current operations. Site I South is used for truck trailer parking and has two roads; a rail spur, truck scales, and a guard shack within its boundary (see Figure 13-4). In addition, the eastern side of the facility's employee parking lot is located within the boundary of Site I South. Installation of a RCRA Subtitle C cover at Site I South would significantly change the topography of the site and would likely result in a reduction of the usable area of the site available for truck trailer parking.

Cerro uses Site I South (and Site I North) as a trailer parking and staging area. The truck traffic at this trailer parking area includes trailers of raw material entering the facility, trailers of product leaving the facility, and moves of the trailers between the trailer parking area and the main operating areas. The amount of traffic in the facility varies during the year, but the traffic levels for February 2012 are typical. During February 2012 a total of 155 raw material trailers and 227 product trailers were managed by the facility. As part of standard operations, each trailer is moved into or out of the trailer parking area a total of 4 times. Therefore, during February 2012 there were a total of 1528 moves. In February there were 22 operating days (i.e., Monday through Friday), so there were an average of 69 moves per operating day during the month. This traffic would be difficult to manage during construction of a RCRA Subtitle C cover at Site I South.

Institutional controls are common and easily implementable. Construction and O&M of the engineered covers the other remedy components of Alternative 3 are implementable at the site using locally available resources and equipment. Monitoring the performance of these technologies is technically feasible.

Cost - The estimated present value cost for Alternative 3 is **$12.8 million.** Table F-3 presents a summary of capital costs, O&M costs, and a calculation of present value costs for Alternative 3. Costs for Alternative 3 are sensitive to the proximity of suitable borrow materials for the cover system, the quantity of fill required to establish the base contours, and the degree to which existing features at Site I South such as the rail spur, truck scales, and employee parking lot may need to be modified to accommodate the change in elevation.

13.5 DESCRIPTION AND DETAILED EVALUATION OF ALTERNATIVE 4

13.5.1 Description of Alternative 4

Alternative 4 includes the following components:

- Institutional Controls
- Containment Cell O&M
- Monitored Natural Attenuation
- Utility relocation
- Pooled DNAPL Recovery at BR-I
- Capping Site G, Site H, Site I South, and Site L
- Leachate Control at Sites G, H, and I South

Institutional controls, Containment Cell O&M, and monitored natural attenuation were described under Alternative 2 in Section 13.3. Utility relocation, pooled DNAPL recovery, and the engineered covers were described under Alternative 3 in Section 13.4. The additional component in Alternative 4 is leachate control at Sites G, H, and I South.

Leachate Control - The leachate control component would be implemented following, or in conjunction with, the installation of the RCRA Subtitle C caps at Sites G, H, and I South. It conceptually would include installation of a grid of 4-inch diameter wells and installation of pre-treatment systems at Sites G, H, and I South to treat recovered leachate prior to discharging it to the American Bottoms Regional Treatment Facility.

Care would be required during design and installation to prevent extraction of fluids from the underlying SHU or MHU rather than leachate from within the waste matrix. The leachate recovery wells would be installed to the base of the waste layer or the base of the SHU, whichever is shallower. A pre-design investigation would be required to identify any areas where the base of the waste is above the saturated zone. Leachate recovery wells would not be installed in areas where the waste is above the water table unless a perched water zone is discovered above the water table. Considering the heterogeneous nature of the disposal areas, the radius of influence of an individual leachate recovery well may be limited. The leachate recovery wells are assumed to be placed on approximate 100-foot centers with a typical depth of 25 feet below grade. Based on 100-ft spacing, a total of 79 leachate recovery wells would be installed, including 19 at Site G, 21 at Site H, and 39 at Site I South (Figure 13-7).

The leachate recovery wells would be screened across the entire saturated thickness of the fill areas and will be equipped with air-activated recovery pumps that operate only when fluids are present. For planning purposes, the flow rate is estimated to be 1 gpm per well. The conceptual designs for the pre-treatment systems at Sites G, H, and I South include an oil-water separator, sand filter, bag filters, and vessels of granular activated carbon.

13.5.2 Detailed Evaluation of Alternative 4

Overall Protection of Human Health and the Environment - Alternative 4 is protective of human health and the environment. This alternative addresses all of the potential risks to human receptors identified in the HHRA. However, the leachate control system included in Alternative 4 does not provide any significant enhancement to the overall protection of human health and the environment.

The engineered covers in Alternative 4 include RCRA Subtitle C covers at Sites G, H, I South, and L and asphalt pavement with a flexible membrane liner at Site G West. These engineered covers address the RAO for surface and subsurface soil and the RAO for waste and leachate. These covers, in conjunction with the institutional controls, minimize the potential for human exposure to COCs at the fill areas and prevent erosion of the fill areas.

Alternative 4 also achieves the soil vapor RAO. Results of the vapor intrusion HHRA indicate that concentrations of COCs found in soil vapor do not pose an unacceptable risk to human receptors in existing buildings. This alternative includes institutional controls that will prevent construction of new buildings on the source areas without vapor control.

Alternative 4 meets all three groundwater RAOs. Groundwater is not used as a source of drinking water in the area. Although there are some private wells that may be used for outdoor household activities, none are located within or downgradient of the Sauget Area 1 groundwater plumes. The existing ordinances in the Villages of Sauget and Cahokia prohibiting the use of groundwater as a potable water source provide appropriate protection of human health.

As discussed in Section 12.2, a 30-year time to clean is not feasible for the Sauget Area 1 plume, and implementation of the engineered covers and leachate control system would not significantly reduce the time to restore groundwater quality. Groundwater quality will ultimately be restored through monitored natural attenuation, although the time to achieve compliance with MCLs and Class I standards downgradient of the Sauget Area 1 sites is in the range of several hundred years.

Alternative 4 addresses the groundwater RAO that requires preventing groundwater discharges to the Mississippi River from the Sauget Area 1 source areas that result in an unacceptable, adverse ecological impact to the River. As discussed in Section 6.5, the updated regional groundwater flow and transport model (GSI, 2012) was used to quantify the mass flux to the Mississippi River from the Sauget Area 1 plumes with the GMCS off and with the GMCS on. Modeled mass flux results for the year 2020 and beyond indicate that, for all 7 COCs, the GMCS will capture approximately 73% of the modeled mass flux from Sauget Area 1 that reaches the area near the Mississippi River. To the extent that it occurs, the mass flux to the River from the Sauget Area 1 plumes would be located north of the barrier wall in an area that is within the plume areas from other sources, including Sauget Area 2 and the Krummrich plant. Groundwater concentrations along the River north of the barrier wall can be monitored for the Sauget Area 1 COCs using two conceptual point-of-compliance well locations discussed in Section 12.2.3.

Compliance with ARARs - The ARARs identified for the Sauget Area 1 remedial alternatives are listed in Table 13-1. ARARs that govern the closure and post-closure requirements related to landfills include 35 IAC 807, which contains the standards for solid waste landfills, and 35 IAC 724, which contains the standards for owners and operators of hazardous waste treatment, storage and disposal facilities. Although the 35 IAC 807 standards are relevant to Sauget Area 1, they are not appropriate because the hazardous waste landfill requirements of 35 IAC 724 are better suited to site conditions. The engineered covers included in Alternative 4 satisfy identified ARARs for soil and waste present in the fill areas at Sites G, H, I South, and L.

The closure and post-closure care requirements in 35 IAC 724.410a define the following minimum requirements for hazardous waste landfill covers:

1) Provide long-term minimization of migration of liquids through the closed landfill
2) Function with minimal maintenance
3) Promote drainage and minimize erosion or abrasion of the cover
4) Accommodate settling and subsidence so that the cover's integrity is maintained

Items 2 through 4 are relevant and appropriate for Sauget Area 1. Item 1 is relevant but not appropriate to site conditions. The caps included in Alternative 4 either comply with or are substantially equivalent to items 2 through 4.

The caps and leachate collection systems included in Alternative 4 would provide long-term minimization of migrations of liquids through the fill areas. However, long-term minimization of migration of liquids through the fill areas is not appropriate for site conditions at Sauget Area 1 based on the following factors:

- Results from a mass flux evaluation of Site I indicates that estimated mass flux of key COCs from leaching of unsaturated source materials is small compared to estimated mass flux of the COCs due to lateral groundwater flow. (For detailed discussion of the mass flux evaluation see Section 13.4.3.)
- Average estimated waste thicknesses at Sites G, H, and I South are 20 ft, 20 ft, and 25 ft, respectively. Under typical conditions the lower portion of the waste at these sites is below the water table, and the water table can fluctuate by several feet over time based on measurements in monitoring wells near the Judith Lane Containment Cell. Installation of caps to minimize infiltration of rainwater at Sauget Area 1 would not address flushing effects from the rising and falling water table.
- No principal threat liquids or mobile source materials were identified in the wastes above the water table at the Sauget Area 1 sites.
- Impacted groundwater at Sauget Area 1 is addressed by MNA and the Sauget Area 2 GMCS.

Alternative 4 provides a closure which either complies with or meets the substantive requirements of 35 IAC 724.211(b), which requires that the closure controls, minimizes, or eliminates to the extent necessary to adequately protect human health and the environment, post-closure escape of hazardous waste, hazardous constituents, leachate, contaminated runoff, or hazardous decomposition products to the ground or surface waters or to the atmosphere.

The caps in Alternative 4 can be constructed to require minimal maintenance, which meets the substantive requirement of 35 IAC 724.211(a). Periodic maintenance as described in the O&M Plan would be implemented to correct any settling or subsidence and to facilitate any needed repairs to the caps.

Alternative 4 satisfies ARARs relating to groundwater quality standards, including 35 IAC 620.405, which prohibits a person from causing, threatening, or allowing release of contaminants to groundwater resulting in exceedance of groundwater quality standards, and 35 IAC 620.410, which contains the Illinois Class 1 groundwater standards. At the end of the remedial action for Alternative 4 there will not be releases of COCs to groundwater that would result in exceedances of groundwater quality standards, and the Class I groundwater standards would be met by MNA.

Alternative 4 also satisfies various ARARs that address the requirements for groundwater monitoring by owners and operators of hazardous waste disposal facilities. These ARARs include 35 IAC 724.191 through 35 IAC 724.197 and 35 IAC 724.199. The substantive requirements of these ARARs will be met for Alternative 4 by the MNA groundwater monitoring program and by groundwater monitoring of point-of-compliance wells located along the Mississippi River.

Long-Term Effectiveness and Permanence - Alternative 4 is an effective, permanent remedial action that meets the RAOs. The residual risk following implementation of Alternative 4 is small since potential exposure to COCs in soils and waste is significantly reduced. Installation of the engineered covers would be effective at minimizing the potential for human exposure to the soil, waste, and leachate and preventing erosion of the fill areas.

The low-permeability covers reduce the potential mobility of COCs in soil and waste by substantially reducing infiltration of rainwater through the fill areas, and leachate control component removes and treats leachate. However, as discussed in Section 13.4.3, low permeability covers and leachate control will not have any significant effect on time to achieve MCLs and Class I standards in groundwater downgradient of the Sauget Area 1 source areas. Alternative 4 addresses the three RAOs for groundwater, although the time to achieve MCLs or Illinois Class I standards will likely be several hundred years.

The institutional controls will remain in place permanently. The engineered covers, including the Containment Cell, will require long-term maintenance to ensure their effectiveness. The DNAPL recovery system at BR-I will require long-term maintenance as long as this well continues to produce DNAPL. The long-term O&M of the leachate recovery and pre-treatment systems at Sites G, H, and I South will likely require significant investments of labor and resources for system monitoring, backwashing of sand filters, replacement of granular activated carbon, and other maintenance tasks.

Reduction of Toxicity, Mobility or Volume through Treatment - Alternative 4 includes two components that involve treatment: i) off-site incineration of the pooled DNAPL recovered from BR-I; and ii) treatment of leachate pumped from the grid of leachate recovery wells.

Pooled DNAPL recovery at BR-I and off-site incineration will reduce the volume of pooled DNAPL at well BR-I, thereby removing source mass and addressing this principal threat material. As discussed in Section 13.4.2, daily removal of one gallon of DNAPL from BR-I for one year would result in removal of approximately 0.43 kg of chlorobenzene; 16.5 kg of 1,4-dichlorobenzene; 0.037 kg of benzene; and 275 kg of 1,2,4-trichlorobenzene.

Leaching of COCs from wastes in the disposal areas represents a historic source of impact to groundwater and a potential ongoing source in the future. The leachate control component provides a relatively limited reduction in the volume and mass of COCs within the fill areas and will not significantly reduce the time to meet the remedial goals for groundwater downgradient of the Sauget Area 1 source areas.

In the long term, Alternative 4 reduces the toxicity and volume of the COCs in groundwater by monitored natural attenuation.

Short-Term Effectiveness - Short-term risks associated with implementation of this alternative are typical of an engineered cover construction project. These risks include general risks to construction workers as well as significant truck traffic needed to bring the large volume of fill and cover material for construction of the engineered covers. Other risks include the potential for dust emissions or stormwater runoff from areas of affected soils or waste during construction of the covers. There are also risks to workers due to potential contact with wastes during drilling and installation of leachate recovery wells at Sites G, H, and I South.

The potential risks to the community due to dust emissions and stormwater runoff can be managed through measures that will be developed during remedial design. The potential risks to site workers during remedy implementation can be managed by requiring adequate PPE and routine safety procedures that will be specified in a health and safety plan to be developed during remedial design.

Alternative 4 would require an estimated 140,600 cubic yards of fill material and soil to be transported to the sites, which would require >7,000 truck loads and would result in the release of approximately 234,000 pounds of carbon dioxide to the atmosphere (Table 13-2).

Implementability - Alternative 4 could be implemented at Sites G, H, and L. However, at Site I South the construction of a RCRA Subtitle C cover and installation of an extensive grid of leachate recovery wells would be difficult to implement and disruptive to current operations.

As previously noted, Site I South is located at an active industrial facility and is used for truck trailer parking. It has two roads, a rail spur, truck scales, and a guard shack within its boundary, and the eastern side of the facility's employee parking lot is located within the boundary (see Figure 13-4). As discussed in Section 13.4.3, the truck traffic at Site I includes trailers of raw material entering the facility, trailers of product leaving the facility, and moves of the trailers between the trailer parking area (i.e., Site I) and the main operating areas. In February 2012 (a typical month), there were an average of 69 moves per operating day. This traffic would be difficult to manage during construction of a RCRA Subtitle C cover and leachate recovery wells and piping at Site I South.

Installation of a RCRA Subtitle C cover at Site I South would significantly change the topography of the site and would likely result in a reduction of the usable area of the site available for truck trailer parking. The leachate recovery wells would require heavy-duty subsurface vaults to prevent truck traffic from damaging the wells.

Another challenge for implementation of the leachate control component involves installation of underground piping. A network of underground piping would be needed to deliver compressed air to the air-powered pumps at the leachate recovery wells and to route recovered leachate to centrally located pre-treatment systems. The trenching and piping installation activities will be disruptive to current operations at Site I South during the construction period.

Institutional controls are common and easily implementable. Construction and O&M of the engineered covers and the other remedy components of Alternative 4 can be performed using locally available resources and equipment. The long-term O&M of the leachate recovery and pre-treatment systems would likely require significant investments of time and resources for system monitoring, backwashing of sand filters, replacement of granular activated carbon, and other maintenance tasks.

Cost - The estimated present value cost for this alternative is **$22.5 million.** Table F-4 presents a summary of capital costs, O&M costs, and a calculation of present value costs for this alternative.

Costs for this alternative are sensitive to the proximity of suitable borrow materials for the cover system, the quantity of fill required to establish the base contours, the degree to which existing features at Site I South may need to be modified to accommodate the change in elevation, the level of O&M needed for the leachate recovery and pre-treatment systems, and the volume of pre-treated leachate that is sent to the American Bottoms treatment facility for disposal.

13.6 DESCRIPTION AND DETAILED EVALUATION OF ALTERNATIVE 5

13.6.1 Description of Alternative 5

Alternative 5 includes the following components:

- Institutional Controls
- Containment Cell O&M
- Monitored Natural Attenuation
- Utility relocation
- Pooled DNAPL Recovery at BR-I
- Soil or Crushed Rock Covers at Sites G, H, I South, and L
- Pulsed Air Biosparging at Residual DNAPL Areas at Sites G, H, and I South

Institutional controls, Containment Cell O&M, and monitored natural attenuation were described under Alternative 2 in Section 13.3. Utility relocation and pooled DNAPL recovery at BR-I were described under Alternative 3 in Section 13.4. The additional components in Alternative 5 are pulsed air biosparging at the residual DNAPL areas at Sites G, H, and I South and installation of soil or crushed rock covers at Sites G, H, I South, and L.

Pulsed Air Biosparging at Residual DNAPL Areas at Sites G, H, and I South – The operation of the pulsed air biosparging (PABS) systems would be characterized by high flow rate pulsed sparging of atmospheric air to promote in-situ aerobic biodegradation and thereby reduce the mass of COCs in the MHU and DHU. Each system would include a grid of nested injection well pairs screened in the MHU and DHU and connected to a compressor to supply atmospheric air. The well grids would be located in the areas of residual DNAPL in the MHU and DHU that were identified at Sites G, H, and I South during the DNAPL characterization and remediation study, as shown on Figure 13-10.

For planning purposes, the injection well spacing was set at 60 feet (i.e., radial zone of influence of 30 feet), which is consistent with the well spacing discussed in the CH2M Hill tech memo, “Preliminary Options for Oxygen Addition at Sauget Area 1 DNAPL Residual Areas” dated October 7, 2008. Based on 60-ft spacing, a total of 82 well clusters would be installed, including 12 at Site G, 15 at Site H, and 55 at Site I South (see Figure 13-10). It is estimated that a compressor can service 10-15 injection wells. Therefore, the conceptual layout shown on Figure 13-10 includes one PABS system at Site G, one system at Site H, and several separate systems at Site I South. The DNAPL area at Site I South extends beneath former Creek Segment A and into an area of the Cerro facility where several buildings are located. These locations are not suitable for implementation of PABS systems due to the presence of the buildings and the presence of an impermeable liner at the base of former Creek Segment A, which was closed and remediated in 1990-1991.

For planning purposes, it is estimated that pulsed injections of air would occur twice per week for a few hours each event. At the location of each sparge well pair there would also be a passive vent well to recover vapors that would be treated in drums of granular activated carbon. Each drum of granular activated carbon would serve several passive vent wells. Figure 13-11 shows a biosparging conceptual cross section that illustrates well depths and the conceptual zone of subsurface airflow during operation of a PABS system.

Recent performance data from a deep (50 to 150 ft below water table) air sparging system showed that the zone of influence of a sparge well increases with injection depth (Klinchuch, 2007). This suggests the possibility of a zone of influence greater than 30 ft at Sauget Area 1 and consequently a reduced number of injection well pairs required for the PABS systems.

To evaluate the feasibility and effectiveness of full-scale operations, a pilot test would be conducted for a period of approximately one year to determine operational parameters, measure performance characteristics, and verify the optimal spacing of the biosparge well pairs, if the PABS alternative is selected. A draft preliminary pilot test workplan is included in Appendix E.

The pilot test would be conducted at a location to be determined (probably at Site I South) and would include the following: baseline soil and groundwater sampling and testing; installation of four sparge well pairs with passive vent wells; installation of groundwater monitoring wells at and near the pilot test area; construction of the pilot system and piping; operation of the pilot test for one year; and post-test soil and groundwater sampling to estimate COC mass removal. The pilot test would include monitoring and control of emissions from the passive vent wells that are co-located with the sparge well pairs. If appropriate, passive vent wells could also be installed next to key buildings for monitoring during the pilot test.

Following completion of the pilot test and prior to full-scale design of the PABS systems at Sites G, H, and I South, additional soil boring investigations would be needed to more precisely delineate the extent of the residual DNAPL areas shown on Figure 13-10.

Soil or Crushed Rock Covers at Sites G, H, and I South – Alternative 5 includes soil or crushed rock covers at Sites G, H, I South, and L to prevent exposure to the waste and affected soils while providing permeability for air transfer and infiltration of moisture. Soil or crushed rock covers are more appropriate for use with the PABS systems than impermeable RCRA Subtitle C caps. Soil vapors would accumulate in the waste and fill materials in the unsaturated zone beneath the impermeable caps.

The soil or crushed rock covers would meet the requirement of 35 IAC 807. The conceptual footprint of the soil or crushed rock covers at Sites G, H, I South, and L are shown on Figures 13-3 and 13-4.

At Site G, the soil or crushed rock cover would be constructed at the northern portion of the fenced area as shown on Figure 13-3. The conceptual footprint of the soil or crushed rock cover within the fenced area corresponds to the approximate extent of waste and fill based on boundary trenching conducted during the RI. Waste was not found in the southern portion of the fenced area at Site G and, therefore, the soil or crushed rock cover does not include that area. The cross sections of the soil or crushed rock cover for Site G are shown on Figures 13-8 and 13-9, respectively. At Site G West, asphalt pavement would be installed to cap the parking area surrounding the Wiese Engineering building. A soil or crushed rock cover in the Wiese Engineering parking area is not necessary because the PABS system at Site G is located relatively far (~400 feet) from Site G West (see Figure 13-10).

At Site H, which is an undeveloped property, the soil or crushed rock cover would include the entire area of Site H as shown on Figure 13-3. Figures 13-8 and 13-9 show the conceptual cross sections for the soil cover or crushed rock cover at Site H.

At Site I South a crushed rock cover would be constructed instead of a soil cover so that Site I South can continue to be used for truck trailer parking. Site I South is already covered by clean, purchased stone or surplus concrete that was placed to fill depressions and maintain grades for truck trailer parking. A pre-design investigation would be performed to determine the thickness of the existing clean surface materials at Site I South (in order to determine the amount and location of new material required to be added to achieve a minimum of two feet of clean material). The crushed rock cover at Site I South will need to incorporate the existing features of the site, and in some locations the existing pavement may need to serve as the final cover. The conceptual footprint of the Site I South crushed rock cover is shown on Figure 13-4. The cross section of the crushed rock cover for Site I South is shown on Figure 13-9.

At Site L the soil or crushed rock cover would be placed on an area immediately east of Dead Creek Segment B, as shown on Figure 13-3. Figures 13-8 and 13-9 show the conceptual cross sections for the soil or crushed rock cover at Site L.

13.6.2 Performance of Pulsed Air Biosparging

Until a pilot test is performed, it is not possible to precisely estimate the source mass removal that can be achieved in the MHU and DHU using operation of a PABS system. However, some studies have shown that under different circumstances than those in Sauget, source mass removal can result in as much as 75% to 90% mass reduction (Brown et al., 1998; Machackova; Sale et al., 2008; Sperry et al., 2001).

The technical memorandum in Appendix C provides a comparison of i) air sparging with SVE and ii) PABS systems for the Sauget Area 1 sites. The analysis was a planning-level effort based on guidance documents and limited site-specific data (i.e., soil and groundwater concentrations). The memorandum includes an evaluation of performance for a PABS system.

Mass removal processes were modeled based on equations presented in the Air Sparging Design Paradigm (Leeson et al., 2002). Key model inputs and assumptions were:

- The model input value for initial soil contaminant concentration was the highest mean concentration of total VOCs plus total SVOCs at the DNAPL characterization borings. The mean concentration for each boring was calculated using results for samples from within the MHU and DHU. The highest mean concentration of total VOCs plus total SVOCs was 346 mg/kg at A1-14.
- The model input value for initial groundwater contaminant concentration was the highest observed groundwater contaminant concentration for chlorobenzene (i.e., 34,000 ug/L at location AA-I-S1 in the sample from 77-81 ft below grade).
- Biodegradation was assumed to be the only contaminant removal mechanism for the PABS system, with a negligible mass removal contribution from contaminant volatilization into the unsaturated zone.

A pore space air saturation of 5% trapped air can continue to deliver oxygen to the groundwater for at least one day and probably longer after each injection event (Leeson et atl, 2002). Therefore, the PABS systems would be operated for sufficient duration during each pulse to achieve 5% pore space air saturation.

Preliminary modeling of the anticipated performance metrics of the PABS system indicates that the estimated time to achieve source mass removal of 75% is approximately 3.5 years and the estimated time to achieve source mass removal of 90% is approximately 6.5 years. As noted above, it is difficult to predict the actual performance of a source treatment project prior to its application in the field (ESTCP, 2008).

13.6.3 Generation and Management of Soil Vapors During Pulsed Air Biosparging

The limited injection duration (conceptually several hours twice per week) that is characteristic of a PABS system greatly reduces, but does not eliminate, the volume of air that reaches the unsaturated zone, compared to a continuously operated air sparging system. Controlling the volume and frequency of air sparging will be required in order to prevent the vapors generated by the PABS systems from becoming unacceptable risks to indoor workers in nearby buildings. The nearby buildings and their approximate distances from the closest PABS well pairs include: Sauget Village Hall, 200 ft southeast; Cerro Flow Products, 150 ft west; Wiese Engineering building, 400 ft west; and Metro Construction Equipment, 150 ft east (relative to Site G).

Generation of Soil Vapors - Compressed atmospheric air that is sparged into the MHU/DHU well pairs during the twice-weekly pulsed biosparge events will form air channels that extend into the MHU and DHU. The air channels will eventually reach the base of the SHU, as illustrated on the conceptual cross section on Figure 13-11. When the sparging is terminated, the air channels will collapse, forming trapped air bubbles in pore spaces within the MHU and DHU.

The pulsed sparging will be performed using atmospheric air, which contains (by volume) approximately 78% nitrogen, 21% oxygen, and small amounts of other gases, including water vapor. The oxygen fraction in the trapped air bubbles in the MHU and DHU will diffuse into the groundwater and be utilized for biodegradation. However, most of the nitrogen in the trapped air bubbles will not diffuse into groundwater. The trapped air bubbles are likely to be mobilized during subsequent pulsed sparging events and will eventually reach the base of the SHU.

Due to volatilization of COCs in the MHU and DHU during pulsed biosparging events, the air that reaches the SHU will contain measurable concentrations of volatile COCs, especially during the first few months of operation. After this initial period of operation, COC mass removal will be dominated by biodegradation in the MHU and DHU resulting from diffusion of oxygen from trapped air bubbles.

Some of the air bubbles that reach the base of the SHU will move into the fill and waste materials, especially at locations where the waste and fill materials extend to depths at or below the base of the SHU. Some air will also likely accumulate at the base of the SHU, which has a lower permeability than the MHU and DHU.

Management of Soil Vapors - As shown on Figure 13-11, the passive vent wells co-located with the sparge well pairs will be screened to a depth of 35 feet through the fill and waste and into the upper few feet of the MHU. These vent wells are intended as exit points for air bubbles that accumulate at the base of the SHU as well as air bubbles that enter the waste and fill zone. However, most of the air that enters the waste and fill is expected to vent directly through the permeable soil or crushed rock covers that are included as a remedy component of Alternative 5. The volume and frequency of the pulsed air additions will be controlled such that air emissions at the surface do not result in a significant risk. Determining the amount and frequency of pulsed air sparging will be investigated in more detail during the one-year PABS pilot test.

13.6.4 COCs Susceptible to Aerobic Degradation and Estimated Concentrations in Groundwater at Source Areas Before and After Biosparging Treatment

As discussed in Section 6.3, five of the nine indicator COCs in groundwater at Sauget Area 1 are readily degradable under aerobic conditions, including chlorobenzene, 1,4-dichlorobenzene, benzene, vinyl chloride, and 2,4-D. Aerobic degradation of 4-chloroaniline has also been reported. Tetrachloroethene, trichloroethene, and, to a lesser extent, 1,2-DCE, tend to be recalcitrant in aerobic environments.

The technical memo in Appendix D provides a time to clean evaluation for the MHU and DHU for two key COCs, chlorobenzene and 1,4-dichlorobenzene. The regional groundwater flow model was used to develop the time to clean estimates for four scenarios: i) MNA alone; ii) 50% source mass reduction in 2015 plus MNA; iii) 75% source mass reduction in 2015 plus MNA; and iv) 90% source mass reduction in 2015 plus MNA.

The following table lists modeled source area concentrations in 2038 assuming MNA only or MNA plus 50%, 75% or 90% modeled source reduction that occurs in 2015 due to implementation of a source remediation technology (e.g., pulsed air biosparging). The modeled concentrations in the table below were taken directly from Figures A.2, A.3, A.5, and A.6 of the time to clean memo in Appendix D.

MODELED CONCENTRATIONS OF CHLOROBENZENE AND 1,4-DICHLOROBENZENE IN 2038 (ug/L)				
	MNA alone	MNA plus 50% Source Reduction	MNA plus 75% Source Reduction	MNA plus 90% Source Reduction
Site G				
Chlorobenzene (MHU)	2,230	1,100	556	223
Chlorobenzene (DHU)	2,230	1,100	556	223
1,4-Dichlorobenzene (MHU)	NA	NA	NA	NA
1,4-Dichlorobenzene (DHU)	NA	NA	NA	NA
Site H				
Chlorobenzene (MHU)	1,240	621	311	124
Chlorobenzene (DHU)	2,380	1,190	595	238
1,4-Dichlorobenzene (MHU)	3,110	1,550	776	311
1,4-Dichlorobenzene (DHU)	7,250	3,620	1,810	725
Site I South				
Chlorobenzene (MHU)	62,100	31,100	15,500	6,210
Chlorobenzene (DHU)	52,800	26,400	13,200	5,280
1,4-Dichlorobenzene (MHU)	7,250	3,620	1,810	725
1,4-Dichlorobenzene (DHU)	4,220	2,110	1,060	422

1) NA = Not applicable. The regional groundwater model does not have a source concentration term for 1,4-dichlorobenzene at Site G in the MHU and DHU.

13.6.5 Estimated Mass of Principal COCs in Source Areas Before and After Biosparging Treatment

The purpose of the pulsed air biosparing system included in Alternative 5 is to promote in-situ aerobic biodegradation of COCs within the MHU and DHU at the residual DNAPL source zones at Sites G, H, and I South, thereby reducing the mass of COCs in those areas. The total masses of key COCs such as chlorobenzene, 1,4-dichlorobenzene, and benzene in the MHU and DHU within the residual DNAPL source zones can be estimated based on the areas of the source zones (see Figure I-1 in Attachment I), the thickness of MHU and DHU (80 ft), the bulk density of the aquifer material, and the average concentrations of the COCs within the MHU and DHU.

The average concentrations of chlorobenzene, 1,4-dichlorobenzene, and benzene in the MHU and DHU at each source area can be estimated based on analytical results of samples from borings that were advanced during the DNAPL characterization and remediation study (GSI, 2006c). Samples of soil and aquifer matrix were collected at a typical frequency of one sample per 10-ft core.

Appendix I includes a table of analytical results for soil samples collected from borings A1-02, A1-08, A1-09, A1-14, and A1-19, which are located in the residual DNAPL source areas at Sites G, H, and I South. The table also shows the average concentrations of the key COCs at each boring and the estimated mass of COCs for the surrounding residual DNAPL areas that are represented by each boring.

The calculated results were then divided by three and multiplied by three to give a range of potential masses. The following table shows the calculated mass of the key COCs before treatment, the estimated mass range before treatment, and estimated ranges for mass that could be removed assuming 50%, 75%, and 90% source mass reduction.

ESTIMATED MASS REMOVED IN KG ASSUMING 50%, 75% OR 90% MASS REMOVAL					
	Calculated Mass Before Treatment (kg)	Estimated Mass Range Before Treatment (kg)	50% of Mass (kg)	75% of Mass (kg)	90% of Mass (kg)
Benzene	1,100	360 - 3,300	180 - 1,600	270 - 2,500	330 - 2,900
Chlorobenzene	10,200	3,400 - 30,700	1,700 –15,300	2,600 –23,000	3,100 –27,600
1,4-Dichlorobenzene	75,400	25,100 – 226,000	12,600-113,000	18,900-170,000	22,600-204,000

The values for calculated mass before treatment are based on a limited number of soil borings, and conditions in the subsurface are likely to be heterogeneous. Therefore, there is considerable uncertainty in these calculated values.

13.6.6 Detailed Evaluation of Alternative 5

Overall Protection of Human Health and the Environment - Alternative 5 can be implemented in a manner that is protective of human health and the environment.

The engineered covers in Alternative 5 include soil or crushed rock covers at Sites G, H, L; a crushed rock cover at Site I South; and asphalt pavement in the parking areas at Site G West. These engineered covers address the RAO for surface and subsurface soil and the RAO for waste and leachate. These covers, in conjunction with the institutional controls, minimize the potential for human exposure to COCs at the fill areas and prevent erosion of the fill areas.

Alternative 5 can achieve the soil vapor RAO provided that the soil vapors generated during operation of the PABS systems are carefully monitored and managed so as to prevent potential unacceptable risks to indoor workers in nearby buildings. This alternative includes institutional controls that will prevent construction of new buildings on the source areas without vapor controls.

Alternative 5 meets all three groundwater RAOs. Groundwater is not used as a source of drinking water in the area. Although there are some private wells that may be used for outdoor household activities, none are located within or downgradient of the Sauget Area 1 groundwater plumes. The existing ordinances in the Villages of Sauget and Cahokia prohibiting the use of groundwater as a potable water source provide appropriate protection of human health.

As discussed in Section 12.2, a 30-year time to clean is not feasible for the Sauget Area 1 plume. This is the case even if PABS (or any other treatment technology) is implemented and is successful at reducing source mass by 50%, 75%, or even 90%. As documented in Appendix D, if a 90% source mass reduction in the MHU and DHU is assumed to occur in 2015 due to implementation of a treatment technology, it will still probably take >150 years to achieve the MCL for chlorobenzene in the MHU at the conceptual monitoring well location described in Section 13.2.2.

Alternative 5 addresses the groundwater RAO that requires preventing groundwater discharges to the Mississippi River from the Sauget Area 1 source areas that result in an unacceptable, adverse ecological impact to the River. As discussed in Section 6.5, the updated regional groundwater flow and transport model (GSI, 2012) was used to quantify the mass flux to the Mississippi River from the Sauget Area 1 plumes with the GMCS off and with the GMCS on. Modeled mass flux results for the year 2020 and beyond indicate that, for all 7 COCs, the GMCS will capture approximately 73% of the modeled mass flux from Sauget Area 1 that reaches the area near the Mississippi River. To the extent that it occurs, the mass flux to the River from the Sauget Area 1 plumes would be located north of the barrier wall in an area that is within the plume areas from other sources, including Sauget Area 2 and the Krummrich plant. Groundwater concentrations along the River north of the barrier wall can be monitored for the Sauget Area 1 COCs using two conceptual point-of-compliance well locations discussed in Section 12.2.3.

Compliance with ARARs - The ARARs identified for the Sauget Area 1 remedial alternatives are listed in Table 13-1. ARARs that govern the closure and post-closure requirements related to landfills include 35 IAC 807, which contains the standards for solid waste landfills, and 35 IAC 724, which contains the standards for owners and operators of hazardous waste treatment, storage and disposal facilities. Although the 35 IAC 807 standards are relevant to Sauget Area 1, they are not appropriate because the hazardous waste landfill requirements of 35 IAC 724 are better suited to site conditions. The engineered covers included in Alternative 5 satisfy identified ARARs for soil and waste present in the fill areas at Sites G, H, I South, and L.

The closure and post-closure care requirements in 35 IAC 724.410a defines the following minimum requirements for hazardous waste landfill covers:

1) Provide long-term minimization of migration of liquids through the closed landfill
2) Function with minimal maintenance
3) Promote drainage and minimize erosion or abrasion of the cover
4) Accommodate settling and subsidence so that the cover's integrity is maintained

Items 2 through 4 are relevant and appropriate for Sauget Area 1. Item 1 is relevant but not appropriate to site conditions. The engineered covers in Alternative 5 either comply with or are substantially equivalent to items 2 through 4. Engineered covers that provide for long-term minimization of migration of liquids are not appropriate for Sauget Area 1 because:

- Results from a mass flux evaluation of Site I indicates that estimated mass flux of key COCs from leaching of unsaturated source materials is small compared to estimated mass flux of the COCs due to lateral groundwater flow. (For detailed discussion of the mass flux evaluation see Section 13.4.3.)
- Average estimated waste thicknesses at Sites G, H, and I South are 20 ft, 20 ft, and 25 ft, respectively. Under typical conditions the lower portion of the waste at these sites is below the water table, and the water table can fluctuate by several feet over time based on measurements in monitoring wells near the Judith Lane Containment Cell. Installation of caps to minimize infiltration of rainwater at Sauget Area 1 would not address flushing effects from the rising and falling water table.
- No principal threat liquids or mobile source materials were identified in the wastes above the water table at the Sauget Area 1 sites.
- Impacted groundwater at Sauget Area 1 is addressed by MNA and the Sauget Area 2 GMCS.

Alternative 5 provides a closure which either complies with or meets the substantive requirements of 35 IAC 724.211(b), which requires that the closure controls, minimizes, or eliminates to the extent necessary to adequately protect human health and the environment, post-closure escape of hazardous waste, hazardous constituents, leachate, contaminated runoff, or hazardous decomposition products to the ground or surface waters or to the atmosphere.

The soil or crushed rock covers in Alternative 5 can be constructed to require minimal maintenance, which meets the substantive requirement of 35 IAC 724.211(a). Periodic maintenance as described in the O&M Plan would be implemented to correct any settling or subsidence. These covers should provide adequate protection of human health and the environment and will facilitate the operation of the PABS systems for source mass removal in the MHU and DHU.

Alternative 5 satisfies ARARs relating to groundwater quality standards, including 35 IAC 620.405, which prohibits a person from causing, threatening, or allowing release of contaminants to groundwater resulting in exceedance of groundwater quality standards, and 35 IAC 620.410, which contains the Illinois Class 1 groundwater standards. At the end of the remedial action for Alternative 5 there will not be releases of COCs to groundwater that would result in exceedances of groundwater quality standards, and the Class I groundwater standards would be met by MNA.

Alternative 5 also satisfies various ARARs that address the requirements for groundwater monitoring by owners and operators of hazardous waste disposal facilities. These ARARs include 35 IAC 724.191 through 35 IAC 724.197 and 35 IAC 724.199. The substantive requirements of these ARARs will be met for Alternative 5 by the MNA groundwater monitoring program and by groundwater monitoring of point-of-compliance wells located along the Mississippi River.

Long-Term Effectiveness and Permanence – Alternative 5 is an effective, permanent remedy that meets the RAOs for Sauget Area 1.

Reduction of Toxicity, Mobility or Volume through Treatment - Alternative 5 includes two components that involve treatment: i) off-site incineration of the pooled DNAPL recovered from BR-I; and ii) in-situ aerobic biodegradation of COCs in the MHU and DHU by PABS.

Pooled DNAPL recovery at BR-I and off-site incineration will reduce the volume of pooled DNAPL at well BR-I, thereby removing source mass and addressing this principal threat material. As discussed in Section 13.4.2, daily removal of one gallon of DNAPL from BR-I for one year would result in removal of approximately 0.43 kg of chlorobenzene; 16.5 kg of 1,4-dichlorobenzene; 0.037 kg of benzene; and 275 kg of 1,2,4-trichlorobenzene.

The PABS systems are designed to achieve source mass removal through in-situ treatment in the areas where residual DNAPL was encountered in the MHU and DHU. Outcomes for source mass removal are likely to be bracketed between 75% and 90% mass reduction, based on review of various studies (Brown et al., 1998; Machackova; Sale et al., 2008; Sperry et al., 2001). However, a lower mass removal percentage (e.g., 50% mass reduction) is also considered to be a possible outcome. Section 13.6.5 lists estimated ranges for mass removal of chlorobenzene, 1,4-dichlorobenzene, and benzene and discusses the calculation method for estimating the mass prior to treatment. There is considerable uncertainty in these mass estimates.

Short-Term Effectiveness - Short-term risks associated with implementation of Alternative 5 include risks associated with construction of the engineered covers and risks associated with construction and operation of the PABS systems.

The risks associated with construction of the engineered covers include general risks to construction workers as well as significant truck traffic needed to bring the large volume of cover material. Other risks include the potential for dust emissions or stormwater runoff from areas of affected soils or waste during construction of the covers. The potential risks to the community due to dust emissions and stormwater runoff can be managed through measures that will be developed during remedial design.

The risks associated with construction and operation of the PABS systems include: i) risks to workers due to potential contact with wastes during drilling and installation of injection well pairs and vent wells at Sites G, H, and I South; and ii) potential risks to indoor workers at nearby buildings due to the potential for intrusion of soil vapors generated during operation of the PABS systems.

The potential risks to site workers during construction of the engineered covers and during construction and operation of the PABS systems can be managed by requiring adequate PPE and routine safety procedures that will be specified in a health and safety plan to be developed during remedial design.

The potential risks to indoor workers will be addressed by operating and monitoring the PABS systems to control soil vapors and prevent unacceptable risks to indoor workers.

Alternative 5 would require an estimated 93,000 cubic yards of fill material and soil to be transported to the sites, which would require >4,600 truck loads and would result in the release of approximately 155,000 pounds of carbon dioxide to the atmosphere (Table 13-2).

Implementability - Alternative 5 could be implemented at Sites G, H, and L. However, implementing Alternative 5 at Site I South would be difficult and disruptive to current operations, especially the installation of the PABS systems, which include numerous sparge well clusters, extensive underground piping networks, and several equipment enclosures to house the compressors, controls, and drums of granular activated carbon (see Figure 13-10).

As previously noted, Site I South is used for truck trailer parking and has two roads, a rail spur, truck scales, and a guard shack within its boundary. The eastern side of the facility's employee parking lot is located within the boundary of Site I South and is within the area where sparge well pairs would be installed.

Implementation of the PABS component involves installation of underground piping. The PABS system would require a network of underground piping to deliver compressed air to the sparge wells and to route recovered vapors from the passive vapor wells to centrally located equipment compounds. The excavation activities would be disruptive to current operations at Site I South.

As discussed in Section 13.4.3, the truck traffic at Site I includes trailers of raw material entering the facility, trailers of product leaving the facility, and moves of the trailers between the trailer parking area (i.e., Site I) and the main operating areas. In February 2012 (a typical month), there were an average of 69 moves per operating day. This traffic would be difficult to manage during construction of the crushed rock cover and PABS systems at Site I South.

Installation of the cover at Site I South would change the topography of the site and may result in a reduction of the usable area of the site available for truck trailer parking. The biosparge well clusters would require heavy-duty subsurface vaults to prevent damage from truck traffic.

Institutional controls are common and easily implementable. Construction and O&M of the engineered covers and the other remedy components of Alternative 5 can be performed using locally available resources and equipment. The long-term O&M of the PABS systems would likely require significant investments of time and resources for system monitoring and maintenance tasks.

Cost - The estimated present value cost for Alternative 5 is **$14.8 million.** Table F-5 presents a summary of capital costs, O&M costs, and a calculation of present value costs for this alternative. Costs for Alternative 5 are sensitive to the proximity of suitable borrow materials for the cover systems, the degree to which existing features at Site I South may need to be modified to accommodate the change in elevation, and the level of O&M for the PABS systems.

13.7 COMPARATIVE ANALYSIS OF ALTERNATIVES 1 THROUGH 5

The alternatives that were described and evaluated in Sections 13.2 through 13.6 included:

Alternative	Components
Alternative 1	- No action
Alternative 2	- Institutional Controls - Containment Cell Operation and Maintenance (O&M) - Monitored Natural Attenuation (MNA)
Alternative 3	- Institutional Controls, Containment Cell O&M, MNA - Utility Relocation, Pooled DNAPL Recovery at BR-I - Capping Sites G, H, I South, and L
Alternative 4	- Institutional Controls, Containment Cell O&M, MNA - Utility Relocation, Pooled DNAPL Recovery at BR-I - Capping Sites G, H, I South, and L - Leachate Control at Sites G, H, and I South
Alternative 5	- Institutional Controls, Containment Cell O&M, MNA - Utility Relocation, Pooled DNAPL Recovery at BR-I - Soil or Crushed Rock Covers at Sites G, H, I South and L - Pulsed Air Biosparging at Residual DNAPL Areas at Sites G, H, and I South

Overall Protection of Human Health and the Environment - Alternatives 1 and 2 are not protective of human health or the environment because they do not meet the RAOs developed for the affected soils and waste at Sites G, H, and I South.

The engineered covers included in Alternatives 3, 4, and 5 achieve the RAO for surface and subsurface soil and the RAO for waste and leachate. These engineered covers, in conjunction with the institutional controls, minimize the potential for human exposure to COCs at the fill areas and prevent erosion of the fill areas.

Alternatives 1 through 4 achieve the soil vapor RAO. Alternative 5 can achieve the soil vapor RAO provided that soil vapors generated during operation of the PABS systems are carefully monitored and the PABS operations are managed so as to prevent potential unacceptable risks to indoor workers in nearby buildings.

Alternatives 2, 3, 4, and 5 provide the same level of overall protection of human health and the environment with respect to i) preventing ingestion of groundwater exceeding regulatory standards; and ii) preventing groundwater discharges to the Mississippi River from the Sauget Area 1 source areas that result in unacceptable adverse ecological impacts to the Mississippi River.

Alternatives 2, 3, 4, and 5 achieve the groundwater RAO that calls for restoring groundwater quality affected by releases from the Sauget Area1 sites to MCLs and Class I standards, to the extent practicable. However, a 30-year time to clean for the Sauget Area 1 plume is not feasible for any of the alternatives.

Alternatives 2, 3, and 4 rely on MNA for restoring groundwater quality. The time to achieve compliance with MCLs and Class I standards is in the range of several hundred years. Alternative 5 includes MNA as well as source area treatment in the MHU and DHU using PABS. Even if a 90% source mass reduction (the best case) could be achieved in the MHU and DHU in 2015 due to implementation of PABS, it would still be expected to take >150 years to reach the MCL for chlorobenzene in the MHU downgradient of the Sauget Area 1 sites.

Alternatives 2, 3, 4, and 5 address the groundwater RAO that requires preventing groundwater discharges to the Mississippi River from the Sauget Area 1 source areas that result in an unacceptable, adverse ecological impact to the River. As discussed in Section 6.5, the updated regional groundwater flow and transport model (GSI, 2012) was used to quantify the mass flux to the Mississippi River from the Sauget Area 1 plumes with the GMCS off and with the GMCS on. Modeled mass flux results for the year 2020 and beyond indicate that, for all 7 COCs, the GMCS will capture approximately 73% of the modeled mass flux from Sauget Area 1 that reaches the area near the Mississippi River. To the extent that it occurs, the mass flux to the River from the Sauget Area 1 plumes would be located north of the barrier wall in an area that is within the plume areas from other sources, including Sauget Area 2 and the Krummrich plant. Groundwater concentrations along the River north of the barrier wall can be monitored for the Sauget Area 1 COCs using two conceptual point-of-compliance well locations discussed in Section 12.2.3.

Compliance with ARARs – Alternatives 1 and 2 do not comply with ARARs relating to closure and post-closure requirements for landfills due to the absence of an engineered cover or other technology to prevent potential exposure to affected soil and waste present in the fill areas at Sites G, H, I South, and L.

The engineered covers in Alternatives 3, 4, and 5 can be designed and implemented to comply with ARARs relating to closure and post-closure requirements for landfills, specifically 35 IAC 724, which contains the standards for owners and operators of hazardous waste treatment, storage and disposal facilities. Although the 35 IAC 807 standards for solid waste landfills are relevant to Sauget Area 1, they are not appropriate because the hazardous waste landfill requirements of 35 IAC 724 are better suited to site conditions.

The engineered covers in Alternatives 3, 4, and 5 would function with minimal maintenance, would promote drainage and minimize erosion of the cover, and could accommodate settling and subsidence so that the cover's integrity is maintained. Engineered covers that provide for long-term minimization of migration of liquids are not appropriate for Sauget Area 1 because:

- Results from a mass flux evaluation of Site I indicates that estimated mass flux of key COCs from leaching of unsaturated source materials is small compared to estimated mass flux of the COCs due to lateral groundwater flow. (For detailed discussion of the mass flux evaluation see Section 13.4.3.)
- Average estimated waste thicknesses at Sites G, H, and I South are 20 ft, 20 ft, and 25 ft, respectively. Under typical conditions the lower portion of the waste at these sites is below the water table, and the water table can fluctuate by several feet over time based on measurements in monitoring wells near the Judith Lane Containment Cell. Installation of caps to minimize infiltration of rainwater at Sauget Area 1 would not address flushing effects from the rising and falling water table.
- No principal threat liquids or mobile source materials were identified in the wastes above the water table at the Sauget Area 1 sites.

- Impacted groundwater at Sauget Area 1 is addressed by MNA and the Sauget Area 2 GMCS.

Alternatives 3, 4, and 5 provide a closure which either complies with or meets the substantive requirements of 35 IAC 724.211(b), which requires that the closure controls, minimizes, or eliminates to the extent necessary to adequately protect human health and the environment, post-closure escape of hazardous waste, hazardous constituents, leachate, contaminated runoff, or hazardous decomposition products to the ground or surface waters or to the atmosphere.

Alternatives 2, 3, 4, and 5 satisfy ARARs relating to groundwater quality standards, including 35 IAC 620.405, which prohibits a person from causing, threatening, or allowing release of contaminants to groundwater resulting in exceedance of groundwater quality standards, and 35 IAC 620.410, which contains the Illinois Class 1 groundwater standards. At the end of the remedial action for Alternatives 2, 3, 4, or 5 there will not be releases of COCs to groundwater that would result in exceedances of groundwater quality standards, and the Class I groundwater standards would be met by MNA.

Alternatives 2, 3, 4, and 5 also satisfy various ARARs that address the requirements for groundwater monitoring by owners and operators of hazardous waste disposal facilities. These ARARs include 35 IAC 724.191 through 35 IAC 724.197 and 35 IAC 724.199. The substantive requirements of these ARARs will be met for Alternatives 2, 3, 4, and 5 by the MNA groundwater monitoring program and by groundwater monitoring of point-of-compliance wells located along the Mississippi River.

Long-Term Effectiveness and Permanence – Alternatives 3, 4, and 5 are effective, permanent remedial alternatives that meet the RAOs for Sauget Area 1. Alternatives 3 and 4 provide a similar measure of long-term effectiveness and permanence after construction of the engineered covers is complete. Alternative 5 provides a somewhat higher degree of long-term effectiveness by reducing COC concentrations in the MHU and DHU underlying the source areas.

Reduction of Toxicity, Mobility or Volume through Treatment – Alternative 2 provides no reduction of toxicity, mobility, or volume through treatment, except for reduction of toxicity and volume of the COCs in groundwater due to MNA. Alternative 3 includes off-site incineration of the pooled DNAPL recovered from BR-I, which can be considered treatment of this principal threat material.

Alternative 4 includes off-site incineration of the pooled DNAPL recovered from BR-I and treatment of leachate pumped from the grid of leachate wells. As demonstrated during the Remedial Investigation, leachate recovery and treatment will provide a relatively limited reduction in mobility and volume of COCs in the fill areas at Sites G, H, and I South, and will not significantly reduce the time to meet remedial goals for groundwater downgradient of the source areas.

Alternative 5 provides a significantly higher degree of treatment compared to Alternatives 2, 3, and 4. It includes off-site incineration of the pooled DNAPL recovered from BR-I and extensive in-situ aerobic biodegradation of COCs using PABS systems targeting the residual DNAPL areas in the MHU and DHU. Outcomes for source mass removal for the PABS systems are likely to be bracketed between 75% and 90% mass reduction, based on review of various studies (Brown et al., 1998; Machackova; Sale et al., 2008; Sperry et al., 2001), although a lower mass removal (e.g., 50% source mass reduction) is also possible. However, even with the additional cost and complexity of the PABS operations, it would still be expected to take >150 years to reach the MCL for chlorobenzene in the MHU downgradient of the Sauget Area 1 sites.

Short-Term Effectiveness – Alternative 2 has minimal short-term risks to the community and to workers. Alternatives 3, 4, and 5 have similar levels of short-term risks associated with construction of engineered covers, such as truck traffic and the potential for dust emissions and stormwater runoff, which are risks that can be managed.

Alternatives 3 and 4 would require an estimated 140,600 cubic yards of fill material and soil to be transported to the sites, which would require >7,000 truck loads and would result in the release of approximately 234,000 pounds of carbon dioxide to the atmosphere. Alternative 5 would require an estimated 93,000 cubic yards of fill material and soil to be transported to the sites, which would require >4,600 truck loads and would result in the release of approximately 155,000 pounds of carbon dioxide to the atmosphere.

Alternatives 4 and 5 also involve drilling and installation of wells in the fill areas, with associated risks to workers due to potential contact with wastes. These risks can be mitigated using procedures outlined in a health and safety plan that will be developed during remedial design.

In Alternative 5, the risks associated with operation of the PABS systems include potential for risks to indoor workers at nearby buildings due to intrusion of soil vapors generated during operation of the PABS systems. The potential risks to indoor workers will need to be addressed by operating and monitoring the PABS systems to control soil vapors and prevent their migration to nearby buildings.

Implementability – Alternative 2 is readily implementable. The engineered covers in Alternatives 3, 4, and 5 will be difficult to implement at Site I South because of the use of the site for truck trailer parking and because of existing features (e. g., railroad spur, plant road, truck scales). For the same reasons, it will be disruptive to existing operation and difficult to implement leachate control (Alternative 4) or PABS (Alternative 5) at Site I South. These remedy components both require installation of numerous wells, extensive networks of underground piping, and several enclosures for treatment systems and/or compressors.

Cost - The estimated present value costs for the five alternatives are:

- Alternative 1: $0
- Alternative 2: $3.1 million
- Alternative 3: $12.8 million
- Alternative 4: $22.5 million
- Alternative 5: $14.8 million

The following table lists each alternative and indicates the following: i) whether or not the alternative achieves RAOs; ii) whether or not the alternative meets threshold evaluation criteria (i.e., overall protection of human health and the environment and compliance with ARARs); and iii) the estimated present value cost of the alternative, including capital costs and 30 years of O&M.

Summary of the Detailed Evaluation of Alternatives 1 through 5

Alternative	Meets RAOs	Meets Threshold Evaluation Criteria	Estimated 30-Year Present Value Cost ($ million)
Alternative 1 - No Action	No	No	$0
Alternative 2 - Institutional Controls, Containment Cell O&M, MNA	No	No	$3.1
Alternative 3 - Institutional Controls, Containment Cell O&M, MNA - Utility Relocation, Pooled DNAPL Recovery at BR-I - Capping Sites G, H, I South and L	Yes	Yes	$12.8
Alternative 4 - Institutional Controls, Containment Cell O&M, MNA - Utility Relocation, Pooled DNAPL Recovery at BR-I - Capping Sites G, H, I South, and L - Leachate Control at Sites G, H, and I South	Yes	Yes	$22.5
Alternative 5 - Institutional Controls, Containment Cell O&M, MNA - Utility Relocation, Pooled DNAPL Recovery at BR-I - Soil or Crushed Rock Covers at Sites G, H, I South and L - Pulsed Air Biosparging at Residual DNAPL Areas at Sites G, H, and I South	Yes	Yes	$14.8

1) RAOs = Remedial Action Objectives
2) Threshold evaluation criteria include: i) overall protection of human health and the environment; and ii) compliance with Applicable or Relevant and Appropriate Requirements (ARARs).